DISCUSSION DRAFT
NOT APPROVED BY THE DELTA STEWARDSHIP COUNCIL
SUBJECT TO CHANGE

DELTA PLAN AMENDMENTS FOR CONVEYANCE, STORAGE SYSTEMS, AND THE OPERATION OF BOTH

The Delta Stewardship Council (Council) is amending the Delta Plan to promote options for water conveyance, storage systems, and the operation of both as required by Water Code Section 85304. The draft Delta Plan amendment includes a suite of recommendations for Delta water management system operations and supporting infrastructure improvements that, together and in combination with existing Delta Plan policies and recommendations, will further the coequal goals. The draft Delta Plan amendment does not include any new regulations, and therefore it does not apply to a project's consistency with the Delta Plan under Water Code section 85225, or any appeal to the Council of a certification under Water Code sections 85225.5 et seq.

INTRODUCTION

The Sacramento-San Joaquin Delta (Delta) and California's water supply systems are in crisis,[1] and existing Delta water management practices are not sustainable.[2] The recent drought followed by record precipitation underscores this crisis.[3] For decades, human-produced alterations to the Delta's landscape and the operations of water management projects in the Delta and throughout the watershed have combined with multiple other factors to create stressors that imperil the Delta ecosystem and state-wide water supply reliability.[4]

During the mid-1900s when major conveyance and storage facilities of the State Water Project (SWP) and the Central Valley Project (CVP) were authorized and constructed, the State of California (State) was focused on expanding water supplies for economic growth to improve the quality of life throughout California. These projects achieved their purposes of increasing water supplies for agriculture and urban centers, but in doing so they markedly added to the changed physical and ecological conditions in the Delta and its watershed. Subsequently, during the 1970s and 1980s the values informing how we manage water and other natural resources have changed, and the mission of these and other major water storage and conveyance facilities expanded to address native species protection and the maintenance of water quality for human uses in the Delta.[5]

The prolonged drought of 1987-1992 highlighted more than any previous experience the sensitivity of the Delta ecosystem to environmental stressors and the linkage to long-term stability of delta exports. The 1994 Bay-Delta Accord was an historic milestone that brought the State and federal governments together to develop and implement a vision to reverse the

[1] Nichols et al. 1986; Service 2007; Moyle et al. 2013, 2016; Moyle 2014; Luoma et al. 2015
[2] Lund, 2016
[3] Medellín-Azuara et al. 2015; Lund 2016
[4] Hanak et al. 2013; Mount et al. 2012
[5] Lund et al. 2007

declining health of the Delta ecosystem. Subsequent years of study and stakeholder involvement during the CALFED Bay Delta Program resulted in a clearer vision for the future and presaged the need for integrated conveyance and storage and the need to achieve the coequal goals that became the foundation of the 2009 Delta Reform Act and the ~~2013~~ Delta Plan. Despite changes in water system operations and management, ecosystem health has continued to decline in the Delta.[6] An overview of water conveyance and storage project development and operations related to Delta water management is provided as background information in Attachment A.

Today, our existing and planned conveyance and storage projects must meet multiple objectives. The 2009 Delta Reform Act signaled a resolve by the ~~State of California (~~State~~)~~ to implement solutions that would achieve the coequal goals.

> *Coequal goals means the two goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The coequal goals shall be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place.* –Water Code section 85054

The Delta Plan includes policies and recommendations intended to build regional water supply reliability, reduce reliance on the Delta, and improve the Delta's ability to support viable populations of native resident and migratory species and to protect and restore habitats for these species. The Plan also seeks to protect and enhance the unique characteristics of the Delta as a place.

However, our current water management system, as constructed and operated today, is not capable of achieving the Delta Plan's coequal goals.[7] In particular, the use of existing south Delta intake facilities as the sole point of diversion for two large conveyance systems – the State Water Project ~~(SWP)~~ and the Central Valley Project ~~(CVP)~~ – continues to result in entrainment of native fish and changes to water quality and Delta food webs, posing fundamental challenges to improving ecosystem health and providing better water management.[8]

Continuation of the status quo in the Delta is not sustainable with respect to ecosystem health or water supply reliability. The state's most recent drought resulted in severe impacts to listed fish species and a precipitous decline in the delta smelt population. Concurrently, historically low contract allocations and water exports via SWP and CVP facilities caused severe water shortages to some urban and agricultural areas. The drought also triggered the first ever imposition of state-wide emergency water conservation regulations. The experience and impacts of this recent five-year drought, the second multiyear near state-wide drought in less

[6] Cloern et al. 2012
[7] The Delta Plan, Delta Stewardship Council, 2013, as amended, Chapter 3.
[8] Mount et al. 2012

than ten years, underscores the state's and the Delta's vulnerability if we simply maintain the status quo. It also illustrates the pressing need to implement solutions to achieve the coequal goals.

The current decline of aquatic resources in the Delta and the erosion of water supply reliability will continue as the state's changing climate places additional stressors on ecosystem and water management. Extended, intense droughts and more extreme floods are expected to occur more frequently in the future due to climate change.[9] Since 2007, California has experienced nine years of below average runoff and only two years out of eleven ~~where precipitation has been~~have had precipitation amounts above the long-term average. As noted above, California's recent five-year drought has reinforced our understanding of the harmful effects of sustained dry periods on ecosystem health and the correlation between Delta exports and overall State water supply reliability.[10] In stark contrast, historically high combined rainfall and snowpack in late 2016 and early 2017 has called to question the capacity of flood management systems to accommodate future precipitation extremes. Water management and ecosystem sustainability strategies must recognize these climatic trends and work to improve system resiliency.[11]

The experience of two prolonged droughts in the last ten years has also reinforced the need to implement a comprehensive strategy that increases the diversity of regional water supply portfolios, creates more sustainably managed local water sources, and achieves greater water use efficiency.[12] The benefits of water storage during an extended drought were also demonstrated, as were the detriments to water supply reliability, ecosystem health, and groundwater levels when storage is not adequate or is ineffectively managed.[13] Further, the Sustainable Groundwater Management Act (SGMA) has prioritized the need to address severe overdraft of groundwater basins in many areas of California. There is an urgent need to conjunctively manage surface water and groundwater supplies as part of a comprehensive approach to statewide water management, and support the recovery of critically overdrafted basins.[14]

Conveyance, system storage, and operations are part of a broad and integrated portfolio of actions described in the Delta Plan. They are water management tools that are inextricably linked to the management of habitat conditions given the variable nature of the state's water supplies. Deploying one tool independent of the others is ineffective. It is only through the combination of new and improved Delta conveyance, the effective management of existing and

[9] Mann et al. 2017; Das et al. 2013; Pierce et al. 2013; Berg and Hall 2015; Cook et al. 2015; Differbaugh et al. 2015; Savtchenko et al. 2015; Stewart et al. 2015; Williams et al. 2015; Jepsen et al. 2016; Udall and Overpeck 2017
[10] Hanak et al. 2015; Medellín-Azuara et al. 2015; Chang and Bonnette 2016; Lund 2016; Moyle et al. 2016
[11] Jenkins et al. 2004; Opperman et al. 2009; Cahill and Lund 2013; Kiparsky et al. 2014; Null et al. 2014; Lund 2015; Dettinger et al. 2015; Dettinger et al. 2016b
[12] Aghakouchak et al. 2014; Ayars 2013; Cahill and Lund 2013; Null et al. 2014; Bachand et al. 2016; Elias et al. 2016; Fournier et al. 2016; Hanak et al. 2017
[13] U.S. Department of Interior, Bureau of Reclamation (Reclamation) 2015
[14] Jenkins et al. 2004; Castle et al. 2014; Lund 2016; Pulido-Velazquez et al. 2016

expanded surface water and groundwater storage, and the balanced operations of both – combined with other actions and recommendations contained in the Delta Plan – that we can achieve the coequal goals.

The California Water Action Plan[15] lays out decisive actions needed to meet three broad objectives: developing more reliable water supplies, restoring important species and habitats, and providing a more resilient, sustainably managed water resources system (water supply, water quality, flood protection, and environment) that can withstand anticipated and unforeseen pressures in the coming decades. The plan further highlights the need for adaptive management in operating water facilities and in implementing conservation actions, particularly during drought. Action is required throughout California, but the Delta's central role in water management for many regions and citizens of the State makes success in Delta foundational to overall success. The comprehensive actions in the California Water Action Plan include:

- Make conservation a California way of life
- Increase regional self-reliance and integrated water management across all levels of government
- Achieve the coequal goals for the Delta
- Protect and restore important ecosystems
- Manage and prepare for dry periods
- Expand water storage capacity and improve groundwater management
- Provide safe water for all communities
- Increase flood protection
- Increase operational and regulatory efficiency
- Identify sustainable and integrated financing opportunities.

Fortunately, California has taken several steps to implement these actions, as described in the California Water Action Plan 2016 Update.[16]

AMENDING THE DELTA PLAN

To achieve the coequal goals, there is a need to change the way water is managed and water systems are operated in the Delta. Maintaining the status quo will make achieving the coequal goals impossible in the future, and poses a significant risk of continued habitat and species decline and uncertainty in water supplies exported from the Delta. The magnitude of operational changes needed to achieve the coequal goals will not be possible without new investments in

[15] California Natural Resources Agency et al., 2014; http://resources.ca.gov/california_water_action_plan/
[16] California Natural Resources Agency et al. 2016; http://resources.ca.gov/california_water_action_plan/

water infrastructure, namely improvements to water conveyance and storage facilities. Further, operational and infrastructure improvements need to progress together and in coordination with other actions identified in the Delta Plan, such as those related to restoring and enhancing the Delta ecosystem, improving water quality, achieving greater regional self-reliance and reduced reliance on the Delta, and reducing risks to people and property.

There is no single solution to water management in the state, as a whole, and in the Delta in particular.[17] Rather, a combination of near-term and long-term improvements to water conveyance, system storage, and operations are needed.[18] These improvements should seek to balance what can often be competing operational objectives (e.g., protecting threatened fish species and providing reliable water supplies) while minimizing conflicts and protecting the Delta's unique values. Further, as our knowledge of the Delta ecosystem continues to grow there remains significant uncertainty over the effectiveness of planned actions to protect, restore, and enhance the Delta. Consequently, ~~an~~ adaptive management ~~approach~~consistent with the framework outlined in the Delta Plan is critical for all actions that seek to further the coequal goals.

Conveyance improvements in the Delta are needed so that water supplies can be safely moved when they are available and conflicts between water supply deliveries and species protection can be avoided. This will allow exports to be reduced in dry periods when aquatic ecosystem needs are magnified, and promote more effective use of surface and groundwater storage to carry over supplies from wet to dry periods. Conveyance improvements outside the Delta are also needed to better leverage periods when conflicts between water exports and species protection are reduced, such that exported supplies can be managed conjunctively with local surface and groundwater supplies and storage facilities.[19]

Improved water storage in both surface reservoirs and groundwater is needed to accommodate changing hydrology throughout the Delta watershed, to better achieve the beneficial functions of more natural and variable flows, to maintain better temperature conditions in ~~major rivers and~~ the Delta and its tributaries, to allow the storage of water supplies for later use during dry periods, and to sustainably manage the state's aquifers. Moreover, improvements to conveyance and storage must be operated in an integrated manner[20] that furthers achievement of the coequal goals while protecting and enhancing the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place. Throughout the state water managers are actively pursuing opportunities to implement integrated strategies and improvements to water conveyance, system storage, and the operations of both to achieve local and regional goals.

[17] Luoma et al. 2015
[18] Hanak et al. 2017
[19] Hanak et al. 2017
[20] Null et al. 2014

At this juncture, the ~~Delta Stewardship~~ Council, based on historical information and the best currently available science, is proposing to ~~amending~~ amend the Delta Plan to promote options for water conveyance, ~~water~~ storage systems, and the operation~~s~~ of both as required by Water Code Section 85304. Many options have been discussed, proposed, and evaluated by various parties over the past decades, and many options have been implemented (see Attachment A). The ~~proposed~~ recommendations in this draft are an initial proposal for amending the Delta Plan, and ~~these recommendations~~ are based upon the *19 Principles for Water Conveyance in the Delta, Storage Systems, and for the Operation of Both to Achieve the Coequal Goals* adopted by the Delta Stewardship Council in November 2015.[21] ~~These recommendations promote options for conveyance, system storage, and the operation of both in order to contribute to the coequal goals, and describe the outcomes that those options should achieve.~~ The draft amendment describes the types and characteristics of infrastructure that would contribute to the achievement of ~~the achievement of~~ the coequal goals, and also identifies recommended criteria for project proponents to use in evaluating and developing new conveyance and storage projects. The amendment does not prescribe ~~the construction or implementation of specific projects or project proposals, nor does it describe~~ the specific size~~,~~ or location~~, or configuration~~ of ~~such~~ projects.

This amendment is proposed to be included as part of the Delta Plan that was originally adopted by the Council in May 2013. It is intended to work together with existing Delta Plan recommendations and regulatory policies that reduce risk and protect water quality, high-priority habitat areas, Delta as a Place values, and more. This draft amendment should be read in tandem with the Delta Plan, including Delta Plan requirements to reduce reliance on the Delta and increase regional self-reliance, and with the Delta Plan's guidance regarding more natural, functional flows for the ecosystem.

Many agencies, boards, districts, commissions, and other entities are engaged in managing the Delta at federal, state, regional and local levels. Consequently, the recommendations in this draft interact with the planning, implementation, and/or regulatory activities of many entities. Their roles, responsibilities, and missions vary significantly, and none bear sole responsibility for taking action to achieve the coequal goals. Some of the recommendations included in this draft amendment pertain to project proponents who are implementing projects related to conveyance, storage, and their operations, while others pertain to agencies with planning or regulatory review responsibilities. The Council appreciates that agencies with regulatory responsibilities, such as the State Water Resources Control Board and local governments, will have an important role in the review and approval of the actions recommended in this draft amendment. An important function of the Council is to foster collaboration and coordination among the many entities

[21] http://deltacouncil.ca.gov/docs/19-principles-water-conveyance-delta-storage-systems-and-operation-both-achieve-coequal-goals

engaged in projects or planning in the Delta to support decision making that will further the coequal goals.

PROBLEM STATEMENT

Californians have long adapted to the state's highly variable hydrology, characterized by sustained long-term droughts and occasional massive floods.[22] In fact, the state has the most variable annual precipitation patterns of any state within the United States.[23] The existing State and federal water systems were designed principally to address the state's geographic imbalance between abundant, seasonal water supplies north of the Delta, and emerging agricultural, municipal and industrial water demands to the south.[24] In these systems, Delta channels work in combination with water management infrastructure both inside and outside the Delta, including reservoirs, water intakes, pumping facilities, pipelines, and canals. However, much of this infrastructure is aging and vulnerable to natural hazards, and planned components of the State and federal systems were never completed.[25] Recent events have also highlighted the need to inspect and adequately maintain water infrastructure, and ensure adequate long-term funding for ongoing inspections and maintenance.

Today, demands on water infrastructure have fundamentally changed[26] as California's population and diversified economy has grown, societal values informing how we manage water and other natural resources have evolved, our climate ~~has changed~~is changing, and water needs have increased. In addition, populations of several endangered and threatened fish species have declined drastically since the construction of the State and federal water systems and other infrastructure in the Delta watershed. The declines are due to multiple factors, including: entrainment, ~~flow alteration~~changes to natural flow regimes[27] and flow direction, water exports (particularly in dry years), disconnection of rivers and streams from adjacent lands resulting from levee construction and channelization, habitat loss and alteration, urbanization, a warming climate, food availability, predation, and invasive species.[28] Among these many factors, CVP and SWP diversions represent one of the most directly observable sources of fish mortality.[29] Consequently, our water management systems are now called upon to meet

[22] Dettinger and Ingram 2013; Dettinger 2016a
[23] Dettinger et al. 2011
[24] Barnes and Chung 1986; Reclamation 2008
[25] Lund et al. 2007
[26] Lund 2016
[27] Flow regime refers to the regulation of ecological processes in river ecosystems, including the magnitude, frequency, duration, timing, and rate of change of hydrologic conditions (see Glossary, Delta Plan, Delta Stewardship Council, 2013, as amended). In the Delta, seasonal and diurnal flow patterns (flow hydrograph) have been altered by upstream water diversions and reservoir operations, Delta water exports (especially during dry periods), and physical changes to the Delta (channelization, sedimentation, and land use changes). Changes to flow regime have directly affected habitat conditions – including habitat diversity, quality, and extent – and proven harmful to native species. Sources: Bunn and Arthington (2002), Petts (2009), SWRCB (2010).
[28] Healey et al. 2016; Mount et al. 2012
[29] Grimaldo et al. 2009

ecosystem needs not envisioned when they were originally built in an increasingly complex regulatory environment.[30]

This conflict came to a crisis point in 2007 when a federal court significantly curtailed water deliveries south of the delta to protect delta smelt. This launched a seven-year process in the federal courts examining the balance between fish protection requirements under the Endangered Species Act and water operations. Differing federal court orders ensued, some of which protected native fish and restricted water exports, while others recognized urban and agricultural water needs and ordered increased water exports. This period of litigation and court ordered operations of the water projects highlighted the difficulty in resolving this conflict under the status quo system of water conveyance. Reviews by federal and state wildlife agencies have shown that maintaining the status quo conditions will likely result in further deterioration of threatened and endangered fish populations, which will necessitate additional restrictions on water supply exports.[31] If not addressed, this trend may be irreversible and make the achievement of the coequal goals infeasible.

Delta Water Quality and Ecosystem Decline

Human activities and their associated effects on land and water management over the last century and a half have irrevocably changed California's aquatic ecosystems. This is profoundly evident in the Delta, where natural flow patterns have been altered and water has been confined to canalized channels where shallow wetlands once existed.[32] Under the existing configuration for water export, which features single, adjacent points of diversion in the south Delta for both the SWP and CVP, operations result in direct fish losses at the pumps, change the way water and fish move through the Delta, create harmful reverse flow conditions, and place fish at greater risk of predation.[33] These effects have been compounded by the influx of invasive non-native species and changes to habitat quality and quantity upstream from the Delta. The result has been a dramatic decline in native species, including some aquatic species now on the brink of extinction. Despite recent restoration efforts and investments, aquatic species continue to decline.[34] These species also remain highly vulnerable to changing hydrologic conditions such as warmer water temperatures, longer water residence time, increased water clarity, and reduced flow. Further, significant uncertainty exists regarding the effects of projected climate on the hydrology of the Delta watershed and its ecological health.

Water temperatures have warmed and water quality in the Delta has changed over time, as was particularly evident during California's recent drought. Water quality degradation affects not only the Delta ecosystem, but also the ability of waterways to support sustainable agriculture,

[30] Reclamation 1992
[31] National Marine Fisheries Service (NMFS) 2009; NMFS 2014; U.S, Fish and Wildlife Service 2009
[32] Whipple et al. 2012
[33] NMFS 2014; Castillo et al. 2012; Gingras 1997
[34] Moyle et al. 2010, NMFS 2014

recreation, and other quality of life amenities for residents and local communities. Water dedicated to the environment, including storage reserved for water temperature and flow management in the Delta and its tributaries, will become increasingly important over the coming century.[35]

Conflicting Operational Priorities

A fundamental conflict exists today between water operations for ecosystem management (temperature and flow), water quality (both in-Delta and for water exported from the Delta), and water supply reliability. This conflict is magnified during critically dry periods and periods of lower flow when the ecosystem is under increased stress and water suppliers are most vulnerable to shortages. Conflicts in the use and timing of water movement through the Delta for multiple purposes could be more easily addressed by improved water conveyance and storage infrastructure with greater capacity and operational flexibility, combined with investments in regional self-reliance as cited throughout the Delta Plan. This includes increased capacity to safely convey water through the Delta during wetter periods such that exports can be curtailed when fish are at risk, and expanded water storage capacity throughout the state to manage Delta flows and water temperature, and carry over water supplies from wet periods for use in dry periods. Additional storage and conveyance capacity would provide the flexibility needed to adapt to dynamic future conditions and our revolving understanding of ecosystem needs.

An example of this conflict relates to degraded water quality in the Delta during periods of lower flow, which impacts the treatability of water for municipal and industrial uses and creates public health concerns that often must be addressed through higher-cost water treatment processes. Water quality for exports can be improved by moving diversion locations, but doing so also has the potential to degrade water quality for in-Delta uses. These impacts must be carefully monitored and mitigated. Improving, monitoring, and adaptively managing the operation of water systems in the Delta would augment our capacity to balance these priorities and further achievement of the coequal goals.

Changing Conditions

Conflicting priorities in water and ecosystem management will be intensified by climate change, which will alter the magnitude, timing, duration, frequency, and rate of change of stream flows in the Delta watershed.[36] Climate change will result in higher ambient temperatures, reduced Sierra Nevada snowpack, more precipitation falling as rain rather than snow, snow melting earlier and more rapidly, warmer stream temperatures, and higher amounts of water loss

[35] Hanak et al. 2012
[36] Anderson et al. 2008; Huang et al. 2012; Berghuijs et al. 2014; Goulden and Bales 2014; Van Lienden et al. 2014; Savtchenko et al. 2015; Jepsen et al. 2016; Udall and Overpeck 2017

through evapotranspiration.[37] Climate change is also expected to trend toward more frequent and extended periods of drought as well as more frequent and intense floods.[38]

Climate change will also contribute to rising sea levels along California's coast and within its estuaries.[39] Rising sea levels will place additional burdens on the water management system in the Delta in the years to come.[40] Through-Delta conveyance is very likely to experience salinity increases with sea level rise, which will ultimately rise above appropriate concentrations for drinking water and irrigation in some areas of the western Delta if freshwater outflows are not increased.[41] It is projected that salinity at Jersey Point could increase by 23% in the early 21st century (2012-2040) and 88% by the end of the century, assuming an estimated mean sea level rise of 36 inches (92 centimeters (cm)).[42] For the SWP and CVP, a projected 11.8 inches (30 cm) rise in sea level by the mid-21st century would raise salinity enough to reduce by 10% the amount of time that the projects can operate.[43] Reservoir releases to repel salinity are expected to reduce Delta water exports by ~about 10% by 2050 and by about 25% by 2100.[44] In other words, a 1-foot ~~SLR~~ (30 cm) rise in sea level would require almost 500,000 ~~AF~~ acre-feet of additional Delta outflow to meet current Delta salinity requirements.[37] With sea level rise and increasing temperatures, new and expanded water storage will play a critical role in providing adequate flows in the Delta to manage water ~~temperature~~ flow and water quality (salinity) for all uses.

In addition, California's population is expected to increase from about 39 million in 2016 to more than 44 million by 2030.[45] Population growth and increased economic activity, in combination with land-use changes, economically-driven grower choices that favor permanent crops, and demand hardening from advances in conservation and water use efficiency, will alter water demand patterns.[46] Continued progress in urban conservation is likely to substantially offset demand increases due to population growth, and agricultural water demand is expected to decrease over time. Environmental water demands, however, are expected to increase in the coming years.[47] All of these factors will place stress on the existing system of conveyance and storage in the State. This creates a much more difficult situation in which to maintain a healthy Delta ecosystem while providing reliable water supplies.

[37] Anderson et al. 2008; Huang et al. 2012; Berghuijs et al. 2014; Goulden and Bales 2014; Van Lienden et al. 2014; Savtchenko et al. 2015; Jepsen et al. 2016; Udall and Overpeck 2017; Ficklin et al. 2013
[38] Das et al. 2013; Pierce and Cayan 2013; Pierce et al. 2013; Seager et al. 2013; Berg and Hall 2015; Cook et al. 2015; Differbaugh et al. 2015; Stewart et al. 2015; Walton et al. 2017
[39] Griggs et al. 2017
[40] Cayan et al. 2008; National Research Council 2012; Van Lienden et al. 2014
[41] Fleenor and Bombardelli 2013
[42] Van Lienden et al. 2014
[43] Anderson et al. 2008
[44] Dettinger. 2016a
[45] California Department of Finance 2016
[46] Kiparsky et al. 2014; Bauer et al. 2015; Dettinger et al. 2015; Wilson et al. 2016
[47] Hanak et al. 2012

Sustainable Groundwater Management

Many areas of the state rely on groundwater for all or a portion of their water supplies.[48] As demonstrated during California's recent drought, heavy reliance on groundwater can lead to groundwater overdraft, subsidence due to falling groundwater levels, and loss of access to groundwater in some communities. Extraction of groundwater in the Central Valley region, in particular, has reduced both the groundwater level and underground storage capacity due to subsidence.[49] Groundwater pumping in the Central Valley during the drought was estimated to be about five million acre-feet ~~(MAF)~~ in 2014 and about six million acre-feet ~~MAF~~ in 2015.[50]

~~Further, many communities rely on impaired or contaminated groundwater for their water supplies.~~ Disadvantaged communities are disproportionately affected by water resource challenges related to groundwater, as many small and rural communities rely on groundwater for all or a large portion of their supplies.[51] Further, many small and rural communities rely on impaired or contaminated groundwater for their water supplies, and struggle with the cost of providing safe drinking water. During the recent 2012 to 2016 drought, about two-thirds of drought-impacted public water systems and household water outages were in disadvantaged communities, and nearly one-third of drought-impacted systems served cumulatively burdened communities. These impacted communities are concentrated outside the Delta, in the San Joaquin Valley, the North Coast, and the Central Coast.[52] Similar geographic trends were also reported for drought-impacted household water systems (systems with fewer than 15 household connections, including individual household wells or water supplies).[53] Conjunctive management of surface and groundwater supplies, including passive and active groundwater recharge and in-lieu recharge[54], is an important tool for sustainable groundwater management.[55] Improvements to conveyance, system storage, and the operations of both can support conjunctive management and contribute to sustainable groundwater management in many areas of the state, especially disadvantaged communities, and help assure the right to safe, clean, affordable and accessible water for human consumption and domestic use.

Reduced Reliance on the Delta

Many regions of the state rely on the Delta, to varying degrees, to meet their water supply needs. Reducing reliance on the Delta for water supply is essential to providing more flexibility

[48] State Water Resources Control Board (SWRCB) 2015
[49] Famiglietti et al. 2011; Weiler 2014
[50] Howitt et al. 2015
[51] SWRCB 2013
[52] Disadvantaged communities have a median household income of less than 80 percent of the State median. Cumulatively Burdened Communities are those that rank in the top quarter of census tracts in the State for environmental burdens and socioeconomic vulnerability. Source: Feinstein et al. 2017. An interactive map of disadvantaged communities within California can be found at https://gis.water.ca.gov/app/dacs/.
[53] https://mydrywatersupply.water.ca.gov/report/publicpage
[54] In-lieu recharge is the process of temporarily decreasing the amount of groundwater pumped from an aquifer in combination with a proportional increase in surface water deliveries. Decreased groundwater pumping typically occurs in wet years, allowing the aquifer to naturally recharge and be available for use during dry years.
[55] Fournier et al. 2016

in both meeting water supply reliability goals and protecting the ecosystem, especially in times of lower flow when there is maximum stress on both goals. Reducing reliance on the Delta is State policy, along with an associated mandate for improving regional self-reliance (Water Code section 85021), and reducing reliance is a prominent component of the Delta Plan (reflected in regulatory policy WR P1, Appendix G, and performance measures). Many agencies have made significant investments in developing their local and regional supplies, including groundwater banking, on- and off-stream surface water storage, recycled water, and desalinated supplies, while also achieving significant decreases in imported water demand through conservation and water use efficiency efforts. Reduced reliance on the Delta can be achieved through diversification of water supply portfolios at the regional and local levels, which will provide greater overall supply reliability during periods when water exports from the Delta are reduced.

Not all areas of the state have the same opportunities and resources to uniformly reduce reliance on Delta exports. Inland agricultural regions may not produce enough wastewater to replace agricultural irrigation with recycled water, although opportunities to use recycled water for groundwater recharge may be available. Other areas may be challenged by limited ability to dispose of brine, a byproduct of brackish and recycled water desalination, or geology and geography may limit the ability to store significant amounts of water during wetter periods. The cost effectiveness of any local supply strategy is of major importance and a valid criterion for any decision to implement a new local supply, as is avoiding or mitigating significant environmental impacts in the local area. Although new supply development opportunities may vary throughout the State, all regions reliant on Delta exports can reduce their reliance by increased water efficiency and aggressive water conservation.

New and improved conveyance, system storage, and the operations of both can complement water conservation and local supply development activities by providing a more stable and reliable source of supply. Combined with existing Delta Plan regulatory policies and recommendations for reduced reliance, conveyance and storage can provide the flexibility local water managers need to sustainably manage their local supplies and reduce reliance on the Delta, especially during dry periods when the ecosystem is most vulnerable, water quality is degraded, and exports are limited.

Need for New and Improved Conveyance, Water Storage, and the Operations of Both

New and improved conveyance, water storage, and the operations of both—alongside other actions and policies identified in the Delta Plan—are integral to managing the Delta and achieving the coequal goals. They are part of an integrated approach that uses all available water management tools to provide operational flexibility, while striving to achieve a balance among Delta uses recognized by the State. The risk of taking no action is unacceptably high and will lead to additional, irreparable damage to the ecosystem and insufficient water supplies to support a healthy State economy.[56] Maintaining the status quo will make achieving the

[56] Hanak et al. 2017

coequal goals impossible in the future. To address the challenges and to meet the coequal goals, water managers operating California's water supply systems need to integrate their operation to take advantage of regional supply sources and leverage the use of new and existing facilities for conveyance, system storage, and the optimal operations of both.[57]

New and Improved Water Conveyance

The current system of natural and engineered conveyance infrastructure in the Delta lacks sufficient capacity and flexibility to manage water operations to benefit the ecosystem and enhance water supply reliability. System capacity and operational flexibility are needed to create more natural, variable flows and improve temperature conditions to support ecosystem health, maintain water quality for in-Delta uses, and move more water during wetter periods when supplies are available for both environmental and consumptive uses such that we can export less water from the Delta in dryer periods when native fish are more vulnerable.

Current water conveyance infrastructure is also aging and Delta channels are vulnerable to earthquakes, floods, and other hazards. Failure of this infrastructure poses significant risks for environmental harm and water supply disruption.[58] Climate change also is altering precipitation patterns in the Delta watershed and changing the timing and amount of stream flow, affecting water available for both ecosystem management and supply reliability. Sea level rise will increase salinity intrusion into the Delta, degrade water quality for agricultural and municipal uses in and outside the Delta, and alter ecosystem conditions.[59]

For well over 50 years, State, local, and federal entities have worked to identify long-term solutions to protect the beneficial uses of the Delta, including new and improved water conveyance in the Delta. Conveyance options considered over time have taken many different routes, forms, sizes, and configurations.[60] They have included isolated conveyance (moving water across or around the Delta via tunnels, pipelines, and aqueducts); improvements to existing Delta channels and new Delta channels; and combinations of both isolated conveyance and through-Delta channels (also known as dual conveyance). Numerous operational scenarios have also been considered and evaluated that incorporate a range of upstream and in-Delta flow objectives, changed reservoir operations, changes to the timing of water conveyance and exports (seasonally and by year type), and many other regimes. A great body of work exists describing the potential positive and negative effects, risks, and uncertainties associated with different Delta conveyance options:

- If managed for conservation objectives, an isolated conveyance facility (one that moves water over, under, or around the Delta via artificial means) could facilitate more variable

[57] Lund 2016; Gray et al. 2015; Lund et al. 2014; Null 2016
[58] Working Group on California Earthquake Probabilities 2003; Mount and Twiss 2005; Sneed et al. 2013; Farr et al. 2015; Robinson and Vahedifard 2016; Vahedifard et al. 2016
[59] Anderson et al. 2008; Fleenor and Bombardelli 2013; Van Lienden et al. 2014
[60] California Department of Water Resources (DWR) et al. 2016

flow patterns, operating in a way that more closely mimics the natural flows that existed before the CVP and SWP export facilities were constructed and reducing entrainment—two actions scientists consider quite promising.[61] Construction of screened diversion and intake facilities in multiple locations in the Delta would also reduce reliance on the State and federal export facilities in the south Delta. Operation of the existing CVP and SWP export facilities draws water toward the south Delta, which can reverse the natural direction of flow in Old River, Middle River, and other Delta channels. These flow reversals disorient and reposition vulnerable fish populations, resulting in fish losses from entrainment, predation, and capture and release practices. Access to one or more intakes in the northern Delta ~~This~~ would provide operational flexibility to reduce south Delta exports and limit harmful reverse flow conditions, particularly ~~and reduce fish entrainment and associated fish mortality~~ during periods of lower flow, while at the same time managing water quality. Needed improvements to Delta hydrodynamic conditions and aquatic habitat will be more difficult without some suitably operated form of isolated water conveyance.[62]

- Improvements to through-Delta conveyance alone are insufficient to provide effective protection for native fish, and to mitigate current water operation conflicts with listed species that result in export curtailments. Operational history and scientific studies indicate that exclusive dependence on south Delta pumping facilities will continue to cause reverse flow conditions in Old and Middle rivers, drawing salmon and smelt into the interior channels of the Delta where they are vulnerable to predation and entrainment. Further, anticipated changes associated with sea-level rise, land subsidence, invasive species, climate change, and earthquakes will make it impossible to preserve the Delta in its current state.[63] Significant cost is associated with maintaining existing through-Delta conveyance and export operations. In addition to costs associated with improving levees and channels, increased salinity will impose higher water treatment cots on Delta water users on the order of hundreds of millions of dollars per year. The cost of a large-scale levee failure from an earthquake, though difficult to estimate, would also be very high - both in terms of repair and restoration of affected levees and in terms of habitat loss and environmental harm.[64] Although physical improvements to through-Delta conveyance can complement isolated conveyance by providing additional fish protection measures, sole reliance on improved through-Delta conveyance is unlikely to result in achievement of the coequal goals.

- Even with the construction of some form of new isolated conveyance, through-Delta conveyance will remain an important component of the State's water supply system. The implementation of isolated conveyance without consideration of flow needs within

[61] Hanak et al. 2013; Moyle and Bennett 2008; Fleenor et al. 2010
[62] Lund et al. 2008; Hanak et al. 2011; Moyle et al. 2012
[63] Moyle et al. 2012
[64] Lund et al. 2008

existing Delta channels and waterways has the potential for detrimental effects on water quality and associated resources (such as aquatic habitat and species, recreation, and in-Delta water uses). Depending on the location of new intakes, dual conveyance may decrease the salinity of exported water but additional flow releases from upstream reservoirs may be required to meet in-Delta salinity standards. Analyses of different options for dual conveyance indicate that some in-Delta agricultural water users may encounter more frequent periods of high salinity while others may experience the opposite.[65] With sea level rise, crop revenue losses in the Delta are estimated to be similar (less than 0.5%) with either through-Delta conveyance or dual conveyance of Delta exports.[66] To provide flexibility to adapt to changing conditions, conveyance solutions (both through-Delta and isolated conveyance) should be integrated and operated in tandem with ~~through-Delta conveyance and~~ enhanced water storage in the Delta watershed to optimally achieve the coequal goals while protecting and enhancing the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place.

- California's hydrology is highly variable, requiring flexibility in water management operations to adjust to changing conditions. Adaptive management of new conveyance infrastructure in the Delta and its watershed can provide a framework for adjusting operations to changing conditions and our evolving understanding of ecosystem needs.[67] Adaptive management is a central component of the Delta Plan, and a requirement for covered actions under the plan's regulatory policy G P1.

- Large infrastructure projects ultimately have effects on the local environment and communities where the facilities are located. Above-ground isolated conveyance, in either a canal or above-ground pipeline, would permanently impact the landscape of the Delta—including native habitat, agriculture, transportation, recreation, and local communities. In comparison, below-ground conveyance reduces these impacts over the long-term.[68] However, below-ground conveyance – depending on its location, size, design, and associated physical details – still has the potential for impacts to Delta communities during construction, which would span years. Several existing Delta Plan policies (which are regulatory) and recommendations (which are not regulatory) promote protection of Delta communities, land uses, and restoration opportunity areas that may be affected by new infrastructure.

[65] Fleenor and Bombardelli 2013
[66] Medellín-Azuara et al. 2014
[67] Georgakakos et al. 2012
[68] DWR et al. 2016

- ~~For example,~~ Delta Plan regulatory policy DP P2 requires water management infrastructure be sited to avoid or reduce conflicts with existing land uses and those uses described in general plans.

- Delta Plan recommendation DP R5 addresses the need to plan for the provision of adequate infrastructure, including streets and roads. A large-scale infrastructure project – taking place in multiple locations, on land and on waterways, over a decade or more – will impact existing and future planned infrastructure. Plans should be made to accommodate the goals of transportation planning in the affected area, as well as to mitigate those impacts.

- Delta Plan recommendation DP R14 is aimed at enhancing nature-based recreation within the Delta, and recommendation DP 17 promotes enhancing opportunities for visitor-serving businesses. Construction of new conveyance and future maintenance activities can negatively affect visitor-serving recreation and businesses, and thoughtful and collaborative planning is needed to minimize these impacts such that the intent of these recommendations can be achieved, even during an extended construction period.

- ~~Further,~~ Delta Plan regulatory policy G P1 requires covered actions not exempt from CEQA to include applicable feasible mitigation measures identified in the Delta Plan's Program Environmental Impact Report, including those related to impacts to Delta communities.

Advice from the Delta Protection Commission, ~~and~~ affected local communities and local governments, and agencies responsible for protecting and restoring the Delta environment must be considered in selecting conveyance alternatives and mitigation measures. ~~Further, Delta Plan regulatory policy G P1 requires covered actions not exempt from CEQA to include applicable feasible mitigation measures identified in the Delta Plan's Program Environmental Impact Report, including those related to impacts to Delta communities.~~ Minimizing impacts during construction to the normal, daily course of business in the affected communities and minimizing disruptions during normal operations and maintenance activities should be a priority for facility planners. A phased construction schedule, developed in coordination with local governments and communities in the Delta, could help minimize disruptions from large-scale infrastructure construction activities. Mitigation measures appropriate to the physical scale of new conveyance facilities, the length of the construction period, and anticipated maintenance needs should be planned in collaboration with the affected communities to minimize disruptions to residents and businesses. Further, collaboration, communication, and public engagement should continue throughout design, construction and, ultimately, operation and maintenance of new facilities.

- There is a need to address impacts to terrestrial and aquatic species from new infrastructure development in the Delta. Delta Plan regulatory policy ER P3 requires avoidance of or mitigation for significant adverse impacts to high priority habitat restoration areas, including designing projects such that they will not preclude or interfere with future habitat restoration projects in these areas. Habitat mitigation projects should be implemented in advance of construction activities, such that replacement habitat is establish and functioning prior to the start of construction. Furthermore, project proponents should design new or improved Delta conveyance infrastructure ~~should consider and seek~~ to enhance ecosystem restoration opportunities, flood risk reduction, recreation, and quality of life for Delta communities. New flow patterns linked with habitat restoration areas can create opportunities to re-establish important ecological processes associated with interactions between land and water that more closely resemble~~s~~ historical conditions within the Delta.[69] Conveyance infrastructure can and should be designed to enhance the connectivity of surrounding riparian and floodplain habitats, as well as in-Delta habitats, to better support native ecosystems.[70]

- It will take many years to implement large-scale improvements to conveyance infrastructure in the Delta and, even with the construction of such facilities, the CVP and SWP pumping facilities in the south Delta ~~are likely to~~will continue to operate ~~well into the future~~. Various studies have examined the feasibility of installing fish screens at Clifton Court Forebay or the entrance channels to the CVP and SWP pumping facilities. Most fish screens rely on sweeping flows moving past (parallel to) the screen to prevent impingement and entrainment; additionally, the terminal location and large pumping capacity of the CVP and SWP export facilities make it difficult to design a facility with sufficient sweeping flows to safely screen delta smelt and salmon. Further, fish screens would not address the effect that pumping operations have in reversing flows in some Delta channels and drawing fish toward the south Delta, where they would remain subject to predation and other harmful conditions. Given this, there is a need to identify and implement near-term actions to protect native fish and reduce fish losses associated with existing water export facilities, particularly in the south Delta.[71] This includes evaluating structural changes to the export facilities, improving salvage and release operations, and identifying, monitoring, and adaptively managing actions to address predation.[72]

Based on the findings and considerations identified above, new conveyance in the Delta should:

[69] Whipple et al. 2012
[70] Opperman et al. 2009; Hanak et al. 2013; DiFrancesco and Tullos 2014, 2015
[71] California Natural Resources Agency 2016
[72] Grossman 2016; NMFS 2014; Gingras 1997

- Be a combination of new isolated conveyance and improved through-Delta conveyance facilities (dual conveyance) with access to multiple points of diversion, including one or more screened diversions in the north Delta;

- Be resilient to current and future hazards;

- Be adaptively managed and operated to adjust to changing conditions and scientific understanding, providing flexibility in operations to help achieve the coequal goals today and into the future;

- Be designed to avoid or minimize adverse effects while preserving and enhancing opportunities for ecosystem restoration, recreation, sustainable agriculture, and resilient local economies and communities;

- Be constructed and operated to minimize disruptions to the normal, daily course of business in affected communities, including minimizing disruptions during routine operations and maintenance; this includes ~~developing~~ implementing formal, collaborative processes with local governmental representatives to develop detailed construction implementation plans and policies that are responsive to the needs of affected communities, their economic activities, and quality of life during construction and beyond; and

- Be paired with near-term actions to address native fish losses at Delta export facilities.

New and Expanded Water Storage

Improvements to conveyance alone are not sufficient to eliminate conflicts between water exports and species protection, or to optimize water system operations. Those conflicts are at their height during hydrologic extremes, such as droughts and floods. Water storage is an effective water management tool available to even out the variability of the state's hydrology across time and space, and to optimize the benefits of improved conveyance for both the environment and water supply reliability. For this reason, improvements to conveyance must be considered along with increased water storage to ensure that flow, temperature, and water quality needs can be managed in the Delta, now and into the future.

The state's interconnected network of surface water and groundwater storage lacks the capacity and conveyance flexibility to manage ecosystem, water reliability, and public safety needs under the state's highly variable climate. New and expanded surface water reservoirs, improved groundwater storage, and the conjunctive management of both are critical to provide reliable water supplies for all uses, including flow and temperature management to benefit the Delta ecosystem in the face of increasingly intense drought and a changing climate.[73] With climate

[73] Reclamation 2016; Ho et al. 2017

change, reservoirs in the Delta watershed will need to adjust their operations to accommodate warmer and more intense winter storms, more precipitation occurring as rainfall, and earlier spring snowmelt.[74] These changes will make it increasingly difficult to meet water temperature and flow objectives for native fish and water supply reliability for municipal, industrial, and agricultural uses. With current facilities and management practices, shifts in precipitation and runoff will directly affect deliveries and reservoir storage levels for the SWP and CVP. Lower carryover storage is projected for both the SWP and CVP, presenting risks for water supply reliability, hydropower production, and cold water pool storage for fish protection. The warmer climate and significant shift in seasonal runoff will result in consistently lower water delivery capability.[75] Further, warmer and more intense winter storms will require adjustments to reservoir operations to provide adequate space for floods and protect public safety, which may come at the risk of environmental and water supply needs if reservoirs cannot be refilled later in the season. Without new or expanded storage, current conflicts between the use of water for ecosystem management (flow and temperature), water quality (for in-Delta use and exporters), and supply reliability will only intensify.

New or expanded surface water and groundwater storage across the state can contribute in different ways to achieving the coequal goals. Improved water storage in the Delta watershed – both seasonal and permanent – can help manage flow and water quality conditions to support a healthier Delta ecosystem, while maintaining water quality for agricultural and municipal users, recreation, and fisheries. Native fish species may benefit from improved water storage in the Delta watershed, including storage space dedicated to ecosystem benefits such as flow management, water temperature management, other water quality benefits, or providing water supplies to wildlife refuges. However, it is recognized that opportunities for increased surface water storage may be limited by water availability and that onstream reservoirs may be limited by potential ecological impacts.

More water storage – within the Delta watershed, and within the Delta water export area – is also needed to allow water to be moved through the Delta when there are sufficient flows to support ecosystem needs and water can be more safely exported. These water supplies can be used for storage and later delivery when exports must be reduced to protect water quality and native fish. The value of new and/or expanded storage infrastructure should be assessed along with its connectivity to other surface storage, conveyance systems, and groundwater systems to maximize water supply and ecosystem benefits. Given the State's variable hydrology, the ability to operate conveyance in the Delta in a "big gulp, little sip" manner that balances ecosystem and water supply reliability needs is dependent on the availability of water stored in reservoirs and aquifers.

[74] Anderson et al. 2008; Huang et al. 2012; Berghuijs et al. 2014; Goulden and Bales 2014; Van Lienden et al. 2014; Savtchenko et al. 2015; Jepsen et al. 2016; Udall and Overpeck 2017
[75] Anderson et al 2008

Improved Operations of Storage and Conveyance

The operation of water management projects in and tributary to the Delta are subject to laws and regulations administered and enforced by a variety of agencies, including water flow and quality standards as defined by the State Water Resources Control Board. These laws and regulations effect the operation of upstream reservoirs to meet flow and quality standards, and govern the timing and volume of water that may be conveyed through and exported from the Delta. Water operations are also subject to the conditions associated with individual water rights. ~~The~~ Within this regulatory environment, a complex system of State, federal, and local water management infrastructure in the Delta and its watershed is operated to meet diverse and increasingly competing needs.[76]

Many of the state's conveyance and storage systems are inextricably linked by the Delta and surrounding environments, and conveyance and storage must be operated in an integrated manner to realize their full and combined potential. This includes operations to take better advantage of periods of ample supply such that less water is exported during critical dry periods. Operational flexibility is particularly important when considering climate change and uncertainties associated with future water demands.[77] Further, sustained drought conditions are expected to intensify in the future, putting additional stress on the operation of Delta conveyance and water storage infrastructure to meet both ecosystem and water supply needs.

Given these challenges and uncertainties, adaptive management is critical to successfully operating water management facilities in the Delta to achieve the coequal goals, as described in the Delta Plan. The operation of water storage facilities and Delta conveyance systems must be adaptively managed to address specific and measurable operating objectives for ecosystem and water quality requirements, changing climate conditions, and changing water demands.[78] Systems in the Delta must be operated to reduce hydrodynamic and biological impacts of exporting water through Jones and Banks pumping plants and minimize the frequency, magnitude, and duration of reverse flows in Old River and Middle River in order to reduce the likelihood that fish will be diverted from the San Joaquin or Sacramento rivers into the southern or central Delta.[79] Studies suggest that SWP and CVP water diversion impacts on fish can be mitigated by altering the timing of exports, and that fish losses can by minimizing reverse flows during periods when delta smelt and other fish are migrating into the Delta.[80] Conveyance operations must be coordinated with storage operations to provide adequate flows in the Delta to meet the needs of fish and other native species. Integrated or coordinated operation of conveyance and storage, within and outside of the Delta, can also contribute to sustainable

[76] Lund 2016
[77] Georgakakos et al. 2012
[78] Georgakakos et al. 2012; Null et al. 2014; Kistenmacher and Georgakakos 2015; Null and Prudencio 2016; Rheinheimer et al. 2016
[79] NMFS 2016, NMFS 2009
[80] Grimaldo et al. 2009

management of the State's aquifers, promote conjunctive use, leverage local supplies, and reduce reliance on the Delta during dry periods and droughts.

By taking into account effects on the Delta, conveyance outside of the Delta can be operated to complement Delta conveyance and expanded storage. Local conveyance improvements and sustainable water management actions taken outside the Delta can contribute to the coequal goals through a comprehensive, integrated water management approach that considers multiple water supply sources, including but not limited to surface water storage, groundwater, stream flow, imported water, water transfers, stormwater, desalinated water, and recycled water, as applicable.[81]

CONCLUSION

With regard to new and improved infrastructure—relating to water conveyance in the Delta, water storage systems, and the operation of both to achieve the coequal goals—the Delta Plan promotes the design, implementation, and operation of new and improved water conveyance infrastructure and new or expanded water storage that are consistent with the criteria in Sections I, II, and III, below. All promoted options should be managed so Delta water supplies further the coequal goals and incorporate the best currently available science and adaptive management. Performance measures relevant to Delta Plan amendments for conveyance, system storage, and the operation of both are included in Attachment B.

These provisions are recommendations; they are not regulations.

They are intended to provide guidance to agencies implementing projects but do not ~~control~~ apply to a project's consistency with the Delta Plan under Water Code section 85225, or any appeal to the Council of a certification under Water Code sections 85225.5 et seq.

I. NEW AND IMPROVED WATER CONVEYANCE

A. Promote Options for New and Improved Infrastructure Related to Water Conveyance

Subject to completion of environmental review and approval by the lead agency, and applicable regulatory approvals from other public agencies, the following infrastructure options are hereby promoted.

1. The California Department of Water Resources (DWR) and the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) should pursue a dual-conveyance option for the Delta. Dual conveyance is a combination of through-Delta conveyance and isolated conveyance to allow operational flexibility. Dual conveyance alternatives should be

[81] Howitt et al. 2010; Hanak et al. 2012; Howitt et al. 2015

evaluated, and a selected plan designed and implemented, consistent with Section I.B., below. Dual conveyance should incorporate ~~multiple~~ existing and new intakes and facility improvements for both isolated, below-ground conveyance and through-Delta conveyance of State Water Project (SWP) and Central Valley Project (CVP) water supplies from the Sacramento River to the south Delta, as follows:

(a) The isolated conveyance should incorporate one or more new screened intakes that protect native fish and that are operated to minimize harmful reverse flow conditions in Old and Middle rivers while maintaining water quality for in-Delta uses. Isolated conveyance should complement existing and improved through-Delta conveyance to promote operational flexibility, protect water quality, and support ecosystem restoration.

(b) ~~Operational criteria for new and improved conveyance facilities should be consistent with updated State Water Resources Control Board flow criteria adopted pursuant to Water Code 85086(c)(2).~~ To protect the Delta ecosystem, the State Water Resources Control Board should ensure that operational criteria for new and improved conveyance facilities comply with applicable State Water Resources Control Board requirements, including any flow criteria adopted pursuant to Water Code 85086(c)(2).[82]

(c) Dual conveyance requires continued maintenance and further improvement of through-Delta conveyance. Through-Delta conveyance improvements may include channel improvements consistent with the Delta Plan and additional facilities that could provide for improved operations for native fish protection.

2. DWR and local agencies should pursue new intake and conveyance facilities for conveying SWP supplies from the Sacramento River to SWP contractors in Solano and Napa Counties. This is both to protect native fish and improve the quality and reliability of water supplies delivered via the North Bay Aqueduct.

3. Local agencies, in coordination with DWR and Reclamation, should pursue new conveyance facilities or conveyance facility improvements that allow use of multiple Delta intakes associated with the Los Vaqueros Project. This would increase operational flexibility for local, SWP, and

[82] Water Code section 85086(c)(2) provides, "Any order approving a change in the point of diversion of the State Water Project or the federal Central Valley Project from the southern Delta to a point on the Sacramento River shall include appropriate Delta flow criteria and shall be informed by the analysis conducted pursuant to this section. The flow criteria shall be subject to modification over time based on a science-based adaptive management program that integrates scientific and monitoring results, including the contribution of habitat and other conservation measures, into ongoing Delta water management."

CVP municipal and environmental water supplies conveyed from the south Delta.

4. DWR and Reclamation, in coordination with the California Department of Fish and Wildlife, National Marine Fisheries Service and U.S. Fish and Wildlife Service, should evaluate and identify for near-term implementation feasible actions to contribute to reducing fish losses associated with existing pumping operations at the Banks Pumping Plant and Jones Pumping Plant, consistent with the 2009 *Biological Opinion and Conference Opinion on the Long-Term Central Valley Project and State Water Project Operations Criteria and Plan;* the 2009 *Biological Opinion on the Coordinated Operations of the Central Valley Project and State Water Project in California;* and the 2014 *Recovery Plan for Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of California Central Valley Steelhead*. These actions may include, but are not limited to:

   (a) Implementing changes to the operations and physical infrastructure of the facilities where such changes can improve fish screening and salvage operations and reduce mortality from entrainment and salvage.

   (b) Evaluating and implementing effective predator control actions, such as fishery management or directed removal programs, for minimizing predation on juvenile salmon and steelhead in Clifton Court Forebay and in the primary channel at the Tracy Fish Collection Facility.

   (c) Evaluating and implementing effective predation reduction actions associated with salvage operations, such as transporting and releasing fish in multiple locations in the Delta.

   (d) Installing equipment to monitor for the presence of predators and to monitor flows at the fish collection facilities.

   (e) Modifying Delta Cross Channel gate operations and evaluating methods to control access to Georgiana Slough and other migration routes into the interior Delta to reduce diversion of listed juvenile fish from the Sacramento River and the San Joaquin River into the southern or central Delta.

B. Evaluate, Design, and Implement New or Improved Conveyance or Diversion Facilities in the Delta

1. In selecting new and improved Delta infrastructure for conveying SWP and CVP water supplies from the Sacramento River to the south Delta, project proponents ~~should be based on an evaluation of~~should analyze

and evaluate a range of alternatives that includes all of the following ~~analyses~~:

(a) A reasonable range of flow criteria, rates of diversion, and other operational criteria required to satisfy applicable requirements of State ~~or~~ and federal ~~fishery~~ fisheries agencies~~,~~ and the State Water Resources Control Board, and other operational requirements and flows necessary for protecting, restoring, and enhancing the Delta ecosystem under a reasonable range of hydrologic conditions (as described under Section III.B, below). This includes identifying water available for export and other beneficial uses, consistent with water quality requirements of the State Water Resources Control Board.

(b) A reasonable range of dual-conveyance alternatives, including options for the number and location of new intakes, a range of isolated conveyance capacities, through-Delta conveyance improvements, and other facilities that could improve operations for native fish and in-Delta water quality, as applicable.

(c) The potential effects of climate change on the conveyance alternatives under consideration, including possible precipitation and runoff pattern changes and sea level rise estimates consistent with guidance provided by the California Natural Resources Agency, National Research Council, or other appropriate projections.

(d) The potential effects on migratory fish and aquatic resources.

(e) The potential effects on Sacramento River and San Joaquin River flood management.

(f) The resilience and recovery of Delta conveyance alternatives in the event of catastrophic loss caused by earthquake, flood or other natural disaster.

(g) The potential effects of each Delta conveyance alternative on Delta water quality, flows, and water levels, including the effects of these changes on in-Delta water users.

(h) The operational benefits and/or detriments of providing multiple intake locations.

(i) The potential short-term and long-term effects of each Delta conveyance alternative on terrestrial species.

(j) The potential effects of each Delta conveyance alternative on the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place.

(k) The cost-effectiveness of the alternatives in furthering the coequal goals. Cost-effectiveness means the degree to which a project or action is effective in achieving desired outcomes in relation to its cost.[83]

2. Project proponents should design and implement new or improved conveyance infrastructure in the Delta ~~should be designed and implemented~~ consistent with the following parameters:

(a) Located in areas with seasonally favorable freshwater conditions, and areas that are less vulnerable to degradation during sustained droughts and under anticipated future climate change and sea level rise conditions.

(b) Located to avoid impacts to and, where possible, improve conditions for habitat restoration opportunities in priority restoration areas identified in the Delta Plan, and other important restoration opportunity areas identified by the California Department of Fish and Wildlife.

(c) Located, designed, and operated to minimize adverse conditions for native aquatic and terrestrial species, including but not limited to those conditions related to flow direction and water quality.

(d) Designed to avoid or minimize native fish entrainment and impingement.

(e) Designed to balance adverse project impacts against the project's long- and short-term benefits.

(f) Designed to minimize disruptions to transportation and business activities during routine maintenance activities, with consideration given to scheduling planned maintenance activities in consultation with local governments to minimize impacts to residents and businesses, and establishing communication protocols to notify residents of planned and unplanned maintenance activities.

[83] A cost effectiveness analysis assess the degree to which a project or action is effective in achieving desired outcomes in relation to its cost. A cost-effectiveness analysis differs from a cost–benefit analysis, which assigns a monetary value to the outcomes or effects and compares that monetary value to the cost. Cost effectiveness is often applied where it may be inappropriate or difficult to assign monetary value to the outcomes or effects, such as ecosystem benefits or public health outcomes. In the context of evaluating alternatives, a cost effectiveness analysis can help identify the least costly way of achieving a desired benefit.

~~(f)~~(g) Designed to complement the Delta landscape and minimize aesthetic impacts.

(h) Implemented in accordance with detailed project implementation plans ~~that are~~ developed in cooperation with affected communities, local governments, the Delta Protection Commission, and stakeholders to minimize and/or mitigate adverse environmental effects consistent with Delta Plan Policy GP 1, and avoid or reduce conflicts with existing or planned land uses consistent with Delta Plan Policy DP P2~~.~~, and in consideration of Delta Plan recommendations DP R14, DP R16 and DP R17. Project implementation plans should incorporate good neighbor policies to avoid negative impacts on agricultural lands, residents, and business. Items that should be addressed in the plans include, but are not limited to, the following:

(i) Construction sequencing or phasing;

(ii) Temporary and long-term spoils placement;

(iii) Plans for temporary traffic routing that are consistent with local transportation plans, including consideration of permanent improvements to transportation and alternative transportation routes to avoid the most severe impacts to levels of service during construction;

(iv) Effects of construction activities on recreation and other visitor-related activities and businesses, including disruptions to transportation, temporary waterway closures, aesthetic and noise effects, and access to marinas, parks, and other recreation facilities;

(v) Mechanisms for communicating with landowners, communities, and local governments before and during construction;

(vi) Mechanisms by which community members and stakeholders can raise concerns during construction and in association with ongoing facility operations and maintenance; and

~~(i)~~(vii) Legally-permissible project delivery methods which are cost effective and provide for an expedited design and construction timeline that minimizes disruption to affected communities.

C. Improve or Modify Through-Delta Conveyance

1. Project proponents should design, implement, and adaptively manage improved or modified through-Delta conveyance and appurtenant facilities (such as gates or permanent barriers) ~~should be designed, implemented, and adaptively managed~~ to:

   (a) Substantially lessen or avoid impacts and provide net improvements to riparian habitat and channel margin habitat along anadromous fish migratory corridors and, where feasible, enhance conditions for native fish.

   (b) Substantially lessen or avoid impediments and provide net improvements to anadromous fish migration.

   (c) Substantially lessen or avoid impacts to public safety and include or contribute to levee improvements along Old and Middle Rivers consistent with Chapter 7 of the Delta Plan.

   (d) Modify the conveyance capacity or hydraulic characteristics of existing Delta waterways (e.g., improving levees and/or dredging) in a manner that provides multiple benefits, including: taking advantage of periods when water flow and quality conditions are favorable for improving water supply delivery reliability and flexibility and for protecting, restoring, and enhancing the Delta ecosystem; improving floodplain values and functions; improving habitat conditions during fish migration; and reducing flood risks.

II. NEW AND IMPROVED WATER STORAGE

A. Promote Options for New or Expanded Water Storage

Subject to completion of environmental review and approval by the lead agency, and applicable regulatory approvals from other public agencies, options for new or expanded water storage are hereby promoted as follows:

1. Within the Delta watershed, project proponents should design and operate new or expanded offstream or onstream surface water storage projects ~~should be designed and operated to~~consistent with the criteria in Section III.B. to:

   (a) Provide water supply reliability, water quality, operational flexibility to adapt to changing conditions, and ecosystem benefits under variable hydrologic conditions, and, where possible, flood risk management benefits.

   (b) Improve resilience to the effects of climate change, sea level rise, long-term drought conditions, and emergency supply disruptions.

(c) Allow greater flexibility in storing ~~exported Delta~~water supplies during periods when more water is available ~~for export~~, for carryover into periods when Delta exports are reduced.

(d) Take advantage of periods when the water flow, ~~and~~ quality, and environmental ~~conditions are favorable~~requirements of State and federal agencies are being met, for improving water supply delivery reliability and flexibility and protecting, restoring, and enhancing the Delta ecosystem.

(e) Contribute to improved conjunctive management[84] of both surface and groundwater resources to maximize efficient water use and contribute to sustainable management of groundwater basins, consistent with the Sustainable Groundwater Management Act.

2. Within the Delta water export area, project proponents should implement new or expanded surface water storage projects ~~should~~ that improve resilience to the effects of climate change and drought and ~~be~~ are operated to allow storage of exported and local surface water supplied during wetter periods for use during dryer periods when exports from the Delta are reduced. Opportunities to store stormwater and recycled water supplies of suitable quality should also be promoted as a strategy for improved regional water management and reduced reliance on the Delta. This includes projects in the San Francisco Bay Area, San Joaquin Valley, Central Coast region, and Southern California.

3. Within the Delta watershed and Delta water export area, project proponents should implement groundwater storage and extraction projects, including facilities for groundwater withdrawal, recharge, injection, and monitoring~~, should be~~that are consistent with the criteria in Sections II.C below.

4. The State Water Resources Control Board should review and consider revisions to existing regulations to ~~increase~~ facilitate the safe use of recycled water, stormwater, and other local water supplies for groundwater replenishment.

B. Design, Construct and Implement New or Expanded Surface Water Storage

1. Project proponents should design, implement, and adaptively manage new or expanded surface storage projects in the Delta, its watershed, and Delta water export areas ~~should be designed, implemented, and adaptively managed~~ to:

[84] Conjunctive management is the coordinated and planned management of both surface water and groundwater resources to maximize efficient water use. Water is stored in groundwater basis for future use by intentionally recharging the basin during year of above-average surface water supply. See Glossary, Delta Plan, Delta Stewardship Council, 2013, as amended.

(a) Improve resilience of the State's water supply system through demonstration of benefits under current and anticipated future conditions, including climate change, changing water demands, and regulatory conditions.

(b) Contribute to regional self-reliance and reduced reliance on the Delta.

(c) Demonstrate contributions to the goals of the Sustainable Groundwater Management Act ~~(SGMA)~~ by promoting conjunctive use to achieve long-term groundwater basin sustainability.

(d) Enable participation in water exchanges and transfers that benefit the Delta ecosystem and improve regional water supply reliability.

(e) Demonstrate cost-effectiveness, where cost-effectiveness means the degree to which a project or action is effective in achieving desired outcomes in relation to its cost.

~~(e)~~(f) Minimize and mitigate the impacts of storage on stream flows and water quality, including impacts during construction.

2. Project proponents should design and implement new or expanded surface water storage projects in the Delta and Delta watershed, ~~should be designed and implemented~~ where feasible, to further achievement of the coequal goals by:

(a) Providing ~~the ability to store~~for the dedicated storage of water during wet periods for carry over and later use during dry periods, while balancing the benefits of providing more natural, functional flows[85] to the Delta and its tributaries, meeting other ecosystem needs and providing flood risk management benefits.

(b) Enhancing water temperature management on Delta tributaries either directly or through coordinated operations with other facilities.

(c) Incorporating storage space dedicated to ecosystem benefits, such as flow management, water temperature, other water quality benefits, or providing water supplies to wildlife refuges.

(d) Integrating new and/or expanded storage with other existing or planned storage and conveyance systems to provide increased ecosystem and water supply benefits. This includes developing and/or updating coordinated operations plans, and/or agreements with other storage and conveyance systems.

[85] Defined in Chapter 4 of the Delta Plan, Delta Stewardship Council, 2013, as amended.

(e) Contributing to the protection of water quality in the Delta and its watershed for all beneficial uses consistent with the State Water Resources Control Board's Bay-Delta Plan.

(f) Contributing to more natural, functional flows that support ecosystem health.[86]

3. Project proponents should design and implement, where feasible, new or expanded surface water storage projects outside the Delta watershed, but within the Delta water export area, such as projects within the San Joaquin Valley, Central Coast, or Southern California regions, ~~should be designed and implemented, where feasible, consistent with the following parameters~~to:

(a) Contribute to reduced reliance on the Delta and regional self-reliance and, particularly during dry periods, through storage of available water supplies during wet periods for use during dry periods.

(b) Promote conjunctive management of surface and groundwater resources, and contribute to achieving groundwater sustainability goals established pursuant to the Sustainable Groundwater Management Act or applicable local plans, as appropriate.

(c) Contribute to a comprehensive, integrated water management approach that considers multiple water supply sources including, but not limited to, stream flow, groundwater, imported water, stormwater, and recycled water, as applicable.

C. Implement New or Expanded Groundwater Storage

1. Funding, planning, and technical support provided by the State for groundwater projects should:

(a) Promote multiple benefits, minimize harmful effects to the ecosystem, help achieve Bay-Delta Plan objectives, as applicable, and be consistent with guidance from the State Water Resources Control Board and DWR for implementing the Sustainable Groundwater Management Act.

~~(a)~~(b) Promote increased groundwater recharge using locally available water, such as recharge via stream-aquifer interactions, floodwater or stormwater capture, recharge using recycled water, or others~~.~~, provided such actions do not result in harmful impacts to functional flows in local streams.

[86] Defined in the Delta Plan, Delta Stewardship Council, 2013, as amended.

(c) Promote conjunctive management of surface water and groundwater ~~supplies~~resources, including in-lieu recharge.

(d) Promote new or expanded groundwater banking and exchange projects.

(e) Promote the construction of new or improved local conveyance infrastructure to convey water to and from groundwater recharge and recovery facilities.

~~(b)~~(f) Promote the construction of new or improved conveyance infrastructure that interconnects Delta export conveyance facilities with local conveyance facilities.

~~(c)~~(g) Promote implementation of the Central Valley Salt and Nitrate Management Plan and achievement of management goals and priorities for protection of water quality, where appropriate.

~~(d)~~(h) Support wellhead treatment, especially in disadvantaged communities relying on impaired groundwater.

~~(e)~~(i) Demonstrate consistency with applicable Groundwater Sustainability Plans under the Sustainable Groundwater Management Act.

~~(f)~~(j) Include new infrastructure that is consistent with Sections II.C(a)-(c), above.

~~(g)~~(k) Assess the ecosystem and water supply impacts and benefits to the Delta, including providing mitigation, as appropriate.

~~(h)~~(l) Promote opportunities for storage of flood waters (e.g., floodplain storage) or stormwater that can be managed for groundwater recharge.

2. DWR should develop a model ordinance for groundwater recharge that urges cities and counties to incorporate groundwater recharge and storage into land-use planning and zoning, and to protect areas with the highest potential for groundwater recharge from incompatible uses. (Note: A representative map showing the soil suitability index for groundwater banking projects on agricultural lands is shown in Attachment C [Figure C-1].)

3. DWR or the State Water Resources Control Board should prepare a proposal for an incentive program, in coordination with the Department of Conservation or the U.S. Department of Agriculture's conservation programs, for landowners to protect lands with high groundwater recharge potential for the purpose of contributing to sustainable groundwater management.

III. IMPROVE OPERATIONS OF STORAGE AND CONVEYANCE

A. Promote Options for Operations of Storage and Conveyance Facilities

Subject to completion of environmental review and approval by the lead agency, the following options for the operation of conveyance and storage are hereby promoted:

1. DWR and Reclamation should develop a coordinated operation plan for the SWP and CVP to meet State Water Resources Control Board-specified flow and water quality criteria during extended drought conditions lasting up to six years, describing anticipated changes in routine operations to adapt to drought conditions. In developing the plan, DWR and Reclamation should develop criteria for defining appropriate levels or stages of drought affecting the SWP and CVP, in coordination with water contractors and the public. The plan should consider the operation of other storage projects that are not part of the CVP or SWP, which could further achievement of the coequal goals. This plan should be submitted to the Delta Stewardship Council in 2020 and be updated every five years thereafter, or when physical or regulatory changes necessitate an update.

2. DWR and Reclamation should develop an adaptive management plan consistent with the Delta Plan's adaptive management framework[87] for the coordinated operation of SWP and CVP through-Delta conveyance for the purposes of protecting, enhancing, and restoring the ecosystem and maintaining adequate flows, flow direction, water levels, and water quality for Delta agriculture, recreation, and communities ~~in the Delta~~.

3. Lead agencies for new or modified conveyance facilities, and new and expanded storage facilities—including those options identified in I.A. and II.A., above—should develop operational plans consistent with Section III.B., below.

4. To improve water management flexibility and to support coordinated operations with new storage facilities, local agencies—in coordination with DWR and Reclamation, as appropriate—should pursue the following new or improved conveyance facilities outside of the Delta, to reduce reliance on the Delta and promote regional self-reliance:

   (a) Facilities that promote the movement or exchange of SWP, CVP, and local water supplies between the east and west sides of the San Joaquin Valley.

[87] See page 38 of the Delta Plan, Delta Stewardship Council, 2013, as amended.

(b) Facilities that improve groundwater recharge and/or conjunctive use in overdrafted aquifers of the San Joaquin Valley, Tulare Lake Basin, and other Delta water export areas.

(c) Facilities that increase groundwater banking or exchange, or that promote increased use of stormwater, recycled water, desalinated water, or other local water supplies in regions tributary to, or that rely on, Delta water supplies.

B. Operate Delta Water Management Facilities ~~to Specified Targets and Objectives~~Using Adaptive Management Principles

1. Plans for the operation or reoperation of water conveyance and control facilities in the Delta, or new or modified storage facilities in the Delta and its watershed, should incorporate adaptive management consistent with the Delta Plan's adaptive management framework[88] and further achievement of the coequal goals by:

(a) Including specific and measurable operating objectives (consistent with State Water Resources Control Board's Bay-Delta Plan objectives), that address:

(i) Protection for and enhancements to the Delta ecosystem, including improved water temperature management, while reliably delivering water.

(ii) Avoidance or mitigation of adverse effects on in-Delta recreation ~~or~~ and in-Delta water quality, including identifying salinity targets for the south Delta that are designed to prevent severe water quality degradation and toxic events in dry and critically dry years.

~~(ii)~~(iii) Avoidance or mitigation of adverse effects on stream flows and water quality.

(b) Enabling diversions during periods when Delta water flow, quality, and environmental requirements are being met~~water flow and quality conditions are favorable~~ for improving water supply delivery reliability and flexibility to changing conditions, and for protecting, restoring, and enhancing the Delta ecosystem.

(c) Incorporating adaptive management plans, consistent with the Delta Plan's adaptive management framework[89] and developed in coordination with operators and applicable regulatory agency staff, for modifying operations to meet State Water Resources Control

[88] See page 38 of the Delta Plan, Delta Stewardship Council, 2013, as amended.
[89] See page 38 of the Delta Plan, Delta Stewardship Council, 2013, as amended.

Board flow ~~or~~ and water quality ~~objectives~~ requirements, and California Department of Fish and Wildlife conservation and recovery goals, under the following:

(i) Extended drought conditions (more than three years in duration).

(ii) Changed climate conditions including sea level rise and changed hydrologic conditions over the anticipated project life.

(iii) Extreme wet years and flood events.

(d) Demonstrating that projects can contribute to a more reliable water supply, and can protect, restore, and enhance the Delta ecosystem under a range of future conditions, including changing climate and sea level rise projections from the California Natural Resources Agency or National Research Council, or other appropriate projections.

(e) Evaluating the applicability of forecast-informed reservoir operations.

(f) Considering coordination and integration of operations with existing and/or planned conveyance and water storage facilities to maximize their potential to contribute to the goals of the Sustainable Groundwater Management Act~~SGMA~~, and the goals of other applicable programs and plans related to sustainable groundwater, stormwater, and floodwater management.

(g) Reviewing and updating, as needed, the flood space reservation guidelines for upstream reservoirs in coordination with the U.S. Army Corps of Engineers and reservoir owners or operators.

2. Operation plans for new water conveyance facilities in the Delta, and new or expanded storage facilities in the Delta watershed, should:

(a) Ensure that operations are adequately monitored, evaluated, and revised using adaptive management to make progress towards achieving defined performance measures.

(b) Be based upon accurate, timely, and transparent water accounting and budgeting.

~~(b)~~(c) Ensure that operations provide water levels, water flow, and water quality suitable for in-Delta agricultural and recreational uses.

C. Update the Bay-Delta Plan and Consider Drought

1. In developing and implementing updates to the Bay-Delta Plan, and flow ~~objectives~~ requirements for priority tributaries to the Delta to protect beneficial uses in the Bay-Delta watershed, the State Water Resources Control Board should:

   (a) Consider and contribute to achievement of applicable Delta Plan performance measures.

   (b) Require water diverters in the Delta and its watershed that are responsible for meeting Bay-Delta Plan requirements, including but not limited to DWR and Reclamation, to develop a process and plan for meeting applicable ~~Sacramento River~~ flow and water quality ~~objectives during~~ requirements during extended drought conditions (characterized by multiple, successive dry years)~~, for the purposes of furthering~~to further the coequal goals and ~~minimizing DWR and Reclamation's use of~~minimize reliance on temporary urgency change ~~orders~~petitions and related requests.

D. Operate New or Improved Conveyance and Diversion Facilities Outside of the Delta

1. Conveyance facilities outside the Delta should be operated in a manner that takes into account effects on Delta water quality, the timing and magnitude of flows in the Delta, water supplies available for export from the Delta, and effects on opportunities to protect, restore, and enhance the Delta ecosystem.

2. In allocating funding for new water conveyance and conveyance improvement projects outside the Delta that support regional self-reliance, the State should give preference to projects that:

   (a) Reduce reliance on the Delta for water supply during dry and critically dry years by the specific designation, in operational agreements or plans, of carryover storage for beneficial use during these periods.

   (b) Improve conjunctive management of surface and groundwater resources and contribute to achieving groundwater sustainability goals established pursuant to the Sustainable Groundwater Management Act or local plans, as appropriate.

   (c) Support ecosystem enhancement and/or provide more natural, functional flows[90] in the Delta and its tributaries.

[90] Delta Plan, Delta Stewardship Council, 2013, as amended.

(d) Improve the ability of regions that rely on the Delta, for all or a portion of their water supplies, to withstand and adapt to changing current and future hydrologic conditions.

(e) Contribute to a comprehensive, integrated water management approach that considers multiple water supply sources including, but not limited to, stream flow, groundwater, imported water, stormwater, desalinated water, water saved through increased efficiency, and recycled water, as applicable.

E. Promote Water Operations Monitoring Data Management, and Data Transparency

In meeting the requirements of the 2016 Open and Transparent Water Data Act, DWR should coordinate with the Council to incorporate information related to Delta Plan performance measures and links to the Council's online tracking and reporting tools, as appropriate, in an effort to promote transparency and accessibility of data in tracking progress toward achieving the coequal goals.

ATTACHMENT A.

TIMELINE OF MAJOR CONVEYANCE, STORAGE, AND OPERATIONS

Year	Event	Applicability to:		
		Conveyance	Storage	Operations
1923	O'Shaughnessy Dam (Hetch Hetchy Reservoir) completed		✓	
1929	Pardee Dam completed		✓	
	Mokelumne aqueduct completed	✓		
1931	State Engineer Edward Hyatt created the California State Water Plan. The Plan called for construction of 420 foot dam at the town of Kennett (now in the middle of Shasta Lake) and addressed conveyance from Sacramento River Basin to supplement water supplies in the San Joaquin River Basin	✓	✓	✓
1933	State Authorized $170 million to construct the Central Valley Project	✓	✓	✓
1935	Bureau of Reclamation authorized the Central Valley Project which included Kennett (Shasta), Friant, and Contra Costa (Delta) divisions.	✓		
1942	Friant Dam completed		✓	
1945	Shasta Dam completed		✓	
	Madera Canal completed	✓		
1948	Contra Costa Canal completed	✓		
1950	Sacramento Canals unit of the Central Valley Project authorized	✓		
1951	Delta Cross Channel, Delta-Mendota Canal and Friant-Kern Canal completed	✓		
1956	Folsom Dam completed		✓	
1957	California State Water Plan proposed a West Canal on the west side of Sacramento Valley, through the North Delta	✓		
1959	Corning Canal (east canal system) construction completed	✓		
1960	Burns-Porter Act passed creating the State Water Project; the Act authorized Delta facilities for water conservation, water supply in the Delta, transfer water across the Delta, flood and salinity control	✓	✓	✓
1962	South Bay Aqueduct completed	✓		
1964	Red Bluff Diversion Dam completed		✓	
1965	The Interagency Delta Commission recommended the Peripheral Canal	✓		
1969	Department of the Interior adopted Reclamation's Peripheral Canal Feasibility Report	✓		
1973	Delta Environmental Advisory Committee concluded that the Peripheral Canal, properly designed and operated, was necessary to protect the Delta	✓		
1975	California Department of Water Resources considered alternative water transfer facilities in Bulletin 76	✓		✓

DISCUSSION DRAFT
NOT APPROVED BY THE DELTA STEWARDSHIP COUNCIL
SUBJECT TO CHANGE

Year	Event	Applicability to:		
		Conveyance	Storage	Operations
1978 ~~1978~~	Water Rights Decision 1485 adopted by the State Water Resources Control Board - the Decision ordered the Central Valley Project and State Water Project to guarantee certain conditions for water quality protection for multiple beneficial uses			✓
	Water Quality Control Plan for Sacramento-San Joaquin Delta and Suisun Marsh released			✓
	~~New Melones Dam completed~~		~~✓~~	
1979	New Melones Dam completed		✓	
1980	Legislature / Governor signed Senate Bill 200 authorizing the Peripheral Canal	✓		
	Tehama Colusa Canal (west canal system) construction completed	✓		
1982	Proposition 9, which would have authorized Senate Bill 200, defeated	✓		
1983	Alternatives for Delta Water Transfer published by the California Department of Water Resources			✓
1984	The Deukmejian Administration proposed a new, shorter canal to take Sacramento water to existing channels in the central and south Delta. The Legislature never approved the proposal, commonly called "Duke's Ditch."	✓		
1986	Coordinated Operations Agreement of the State Water Project and Central Valley Project signed which formalized 1970's annual agreements between the two projects for integrated operations as well as developed a common allocation model – the California Water Resources Simulation Model, CALSIM	✓	✓	✓
1991	Central Valley Project Improvement Act Passed – Protects Salmon and Striped Bass	✓	✓	✓
1993	Delta smelt are listed as a threatened species under the Endangered Species Act by both state and federal agencies			✓
1994	Delta Accord signed – CALFED began			✓
1995	Bay-Delta Water Quality Control Plan adopted by the SWRCB and becomes the basis for Decision 1641			✓
1997	Los Vaqueros Project completed		✓	
	The Kern Water Bank began operating under a Habitat Conservation Plan/Natural Community Conservation Plan executed by the Kern Water Bank Authority.	✓	✓	✓
1998	The CALFED Bay Delta Program developed three alternatives for moving water through or around the Delta as well as plans for ecosystem restoration, a multi-species habitat conservation plan, a levee repair strategy, and reservoir planning	✓	✓	✓

DISCUSSION DRAFT
NOT APPROVED BY THE DELTA STEWARDSHIP COUNCIL
SUBJECT TO CHANGE

Year	Event	Applicability to:		
		Conveyance	Storage	Operations
1999	State Water Resources Control Board Water Right Decision 1641 amended water right licenses and permits for the Central Valley Project and State Water Project to assure protection of beneficial uses in the Delta and grants the California Department of Water Resources and the Bureau of Reclamation Joint Point of Diversion capabilities	✓		✓
	Diamond Valley Lake dams (West Dam, East Dam and Saddle Dam) completed		✓	
2000	CALFED approved and began to consider Alternative Conveyance (Peripheral Canal) if alternate measures fall through	✓		
2000	CALFED Bay-Delta Program Final Programmatic Environmental Impact Report/Environmental Impact Statement and Record of Decision released established a preferred program alternative for a through-Delta approach to conveyance			✓
2001	Joint California Department of Water Resources and Bay Delta Authority planning study to evaluate in-Delta storage options released		✓	
2002	The Integrated Storage Investigation developed *North of the Delta Offstream Storage Investigation* report which outlined the development of a new reservoir (Sites reservoir)		✓	
	California Department of Water Resources issued the CALFED Surface Storage Investigations Progress Report to provide information on the status of ongoing CALFED surface storage investigations		✓	
2004	Long-Term Central Valley Project Operations Criteria and Plan released by the Bureau of Reclamation			✓
	In-Delta Storage Program State Feasibility Study released by the California Department of Water Resources and California Bay-Delta Authority (Supplemental Report released in 2006)		✓	
2005	Final Revised Water Quality Control Plan from the California Department of Water Resources and Bureau of Reclamation released			✓
2006	A steering committee was formed to prepare an approach for developing the Bay Delta Conservation Plan which developed a habitat conservation plan as well as a series of conveyance alternatives	✓		
	State Water Resources Control Board Order WR 2006-006 required the Department of Water Resources and the Bureau of Reclamation to meet water quality objectives for salinity in the Southern Delta			✓
	Revised Bay-Delta Plan adopted by the State Water Resources Control Board			✓
	Delta Vision created to “develop a durable vision for sustainable management of the Delta”			✓

DISCUSSION DRAFT
NOT APPROVED BY THE DELTA STEWARDSHIP COUNCIL
SUBJECT TO CHANGE

Year	Event	Applicability to:		
		Conveyance	Storage	Operations
2008	Central Valley Project and State Water Project Operations Criteria and Plan Biological Assessment Released by the Bureau of Reclamation			✓
2008	Biological Opinion from the United States Department of Fish and Wildlife on Long-Term Operations of the Central Valley Project and State Water Project concluded that operations jeopardize the continued existence of the delta smelt	✓		✓
	Senate Bill X2 1 (Water Code 83002) passed and provided funding to the California Department of Water Resources to identify potential options for the reoperation of the state's flood protection and water supply systems that will optimize the use of existing facilities and groundwater storage capacity		✓	✓
2009	Biological Opinion from National Oceanic and Atmospheric Administration on Long-Term Operations of the Central Valley Project and State Water Project concluded that operations jeopardize the continued existence of several endangered species	✓		✓
	Delta Reform Act passed; Section 85304 called for "The Delta Plan shall promote options for new and improved infrastructure relating to the water conveyance in the Delta, storage systems, and for the operation of both to achieve the coequal goals"	✓	✓	✓
2010	Delta smelt listed as endangered under the Endangered Species Act			✓
	The first administrative draft of the Bay Delta Conservation Plan released to the public for review (second draft released in 2012)	✓		✓
	California Department of Water Resources tracked, coordinated, and expanded feasibility studies on the CALFED storage projects through their Surface Storage Program	✓		
2013	Delta Plan adopted by Delta Stewardship Council	✓	✓	✓
	Bay Delta Conservation Plan was modified once again to address comments regarding balance costs, engineering design, and ease of construction while reducing local dislocation and disturbance in the Delta	✓		✓
	California Department of Water Resources released the Bay Delta Conservation Plan Draft Environmental Impact Report/Environmental Impact Statement for public review	✓		✓
	Delta Independent Science Board released review of Bay Delta Conservation Plan Draft Environmental Impact Report/Environmental Impact Statement ~~in 2014~~ and found that the presentation made it difficult to compare alternatives and evaluate the critical underlying assumptions	✓		✓

DISCUSSION DRAFT
NOT APPROVED BY THE DELTA STEWARDSHIP COUNCIL
SUBJECT TO CHANGE

Year	Event	Applicability to:		
		Conveyance	Storage	Operations
2014	*Recovery Plan for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead* published by the National Oceanic and Atmosphere Administration			✓
	Council Chairman Randy Fiorini authored an issue paper, *Smaller May Be Better at Getting Storage Projects off the Ground*, which included recommendations for storage		✓	
	California voters approved the passage of Proposition 1 provided $2.7 billion dollars for new water storage projects		✓	
2015	Administration indicated that the state will forgo the Bay Delta Conservation Plan and work on two separate plans to address conveyance improvements through the California WaterFix and provide near-term habitat restoration through the California EcoRestore	✓		✓
	Bay Delta Conservation Plan Partially Recirculated Draft Environmental Impact Report/Supplemental Environmental Impact Statement released and reviewed by Delta Independent Science Board	✓		✓
	Council adopted the *19 Principles for Water Conveyance in the Delta, Storage Systems, and for the Operation of Both to Achieve the Coequal Goals*	✓	✓	✓
	Bay Delta Conservation Plan /California WaterFix Final Environmental Impact Report/Environmental Impact Statement released by the California Department of Water Resources and the Bureau of Reclamation	✓		✓
	Reinitiation of consultation on the Coordinated Long Term Operations of the Central Valley Project and State Water Project			✓
	Water Commission developed the Water Storage Investment Program		✓	
2016	Delta Smelt Resiliency Strategy published by the California Natural Resources Agency			✓
2017	Council discussed the Discussion Draft Delta Plan Amendment for Water Conveyance, System Storage, and the Operation of Both	✓	✓	✓

1

ATTACHMENT B.

PERFORMANCE MEASURES RELEVANT TO DELTA PLAN AMENDMENTS FOR CONVEYANCE, SYSTEM STORAGE, AND THE OPERATION OF BOTH

The Delta Reform Act of 2009 requires the Delta Plan to include performance measures that enable the Council to track progress in meeting its objectives. These performance measures are to include quantitative or other "measureable assessments of the status and trends" of the health of the Delta, as well as the reliability of the state's water supply exported from the Sacramento and San Joaquin river watersheds (Water Code Sections 85211 and 85308).

The Delta Plan, adopted in 2013, contained a set of performance measures developed to monitor performance of Delta Plan policies and recommendations. The Delta Plan stated that the Council would continue to work with scientific, agency, and stakeholder experts to refine the Delta Plan's performance measures. The Council's first refinement effort involved a rigorous public process culminating in the Council's February 2016 adoption of new and refined performance measures (see Appendix E of the Delta Plan).

Three types of performance measures are identified for the Delta Plan: administrative, output, and outcome. Administrative performance measures describe decisions made by policy makers and managers to finalize plans or approve resources (funds, personnel, projects) for implementation of a program or a group or programs. As the discussion draft amendment for conveyance, system storage, and the operation of both is further developed and refined, new administrative performance measures will be identified to assess progress in achieving the recommendations contained therein.

Outcome performance measures evaluate responses to management actions or natural outputs. Output performance measures evaluate the factors that may be influencing outcomes and include on-the-ground or physical implementation of management actions (such as acres of habitat restored or acre-feet of water released) as well as natural phenomena outside of management control (such as a flood control, earthquake, or ocean conditions. Outcome and output performance measures relevant to the discussion draft Delta Plan amendments for conveyance, system storage, and the operation of both are listed below. Additional performance measures related to flood and seismic risks to facilities are included in Chapter 7 and are currently undergoing revisions through the amendment of the Delta Levee Investment and Risk Reduction Strategy.

OUTCOME PERFORMANCE MEASURES

PM 3.4 *Demonstrate a measureable reduction in reliance on the Delta at the regional level based on individual water supplier reports.*

PM 3.9. *Decrease in Delta exports during critically dry years and an increase in Delta exports during wet years.*

PM 4.2 *Restoring a healthier estuary using more natural functional flows, including in-Delta flows and tributary input flows to support ecological floodplain processes (e.g., spring pulse flows along the Sacramento River, and more gradual recession flows at the end of the wet season).*

PM 4.6 *Achieve the State and federal "doubling goal" for wild Central Valley salmon relative to the period of 1967-1991 levels. Trends will be derived from long-term salmon monitoring surveys conducted by the U.S. Fish and Wildlife Service, California Department of Fish and Wildlife, and others.*

OUTPUT PERFORMANCE MEASURES

PM 6.3 *The Department of Water Resources begins constructing the North Bay Aqueduct Alternate Intake Project by the end of 2018 after the environmental impact report is completed.*

ATTACHMENT C.

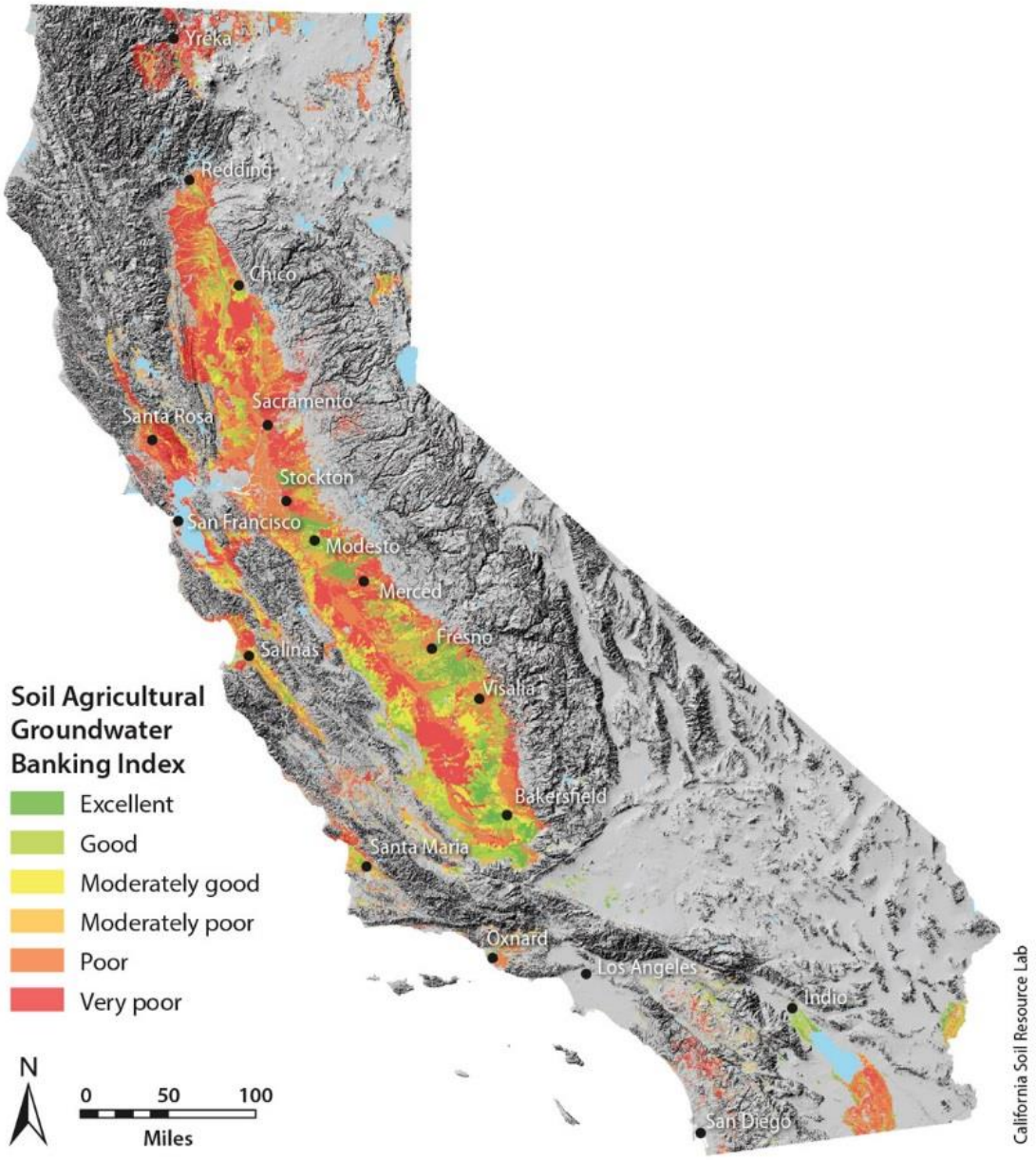

Figure A-1. Soil Agricultural Groundwater Banking Index Identifying Potential Areas for Groundwater Banking on Agricultural Lands

Source: Green, A.T. et al. 2015. California Agriculture. Soil suitability index identifies potential areas for groundwater banking on agricultural lands. Available at: http://ucanr.edu/repositoryfiles/cav6902p75-157818.pdf

ATTACHMENT D.

REFERENCES

Aghakouchak, A., D. Feldman, M. J. Stewardson, J.-D. Saphores, J, S. Grant, and B. Sanders. 2014. Australia's drought: lessons for California. Science 343:1430−1431. http://science.sciencemag.org/content/343/6178/1430.

Anderson, J., F. Chung, M. Anderson, L. Brekke, D. Easton, M. Ejeta, R. Peterson, and R. Snyder. 2008. Progress on incorporating climate change into management of California's water resources. Climatic Change 87: S91-S108. https://link.springer.com/article/10.1007/s10584-007-9353-1.

Ayars, J. E. 2013. Adapting irrigated agriculture to drought in the San Joaquin Valley of California. Pages 25-39 in K. Schwabe, J. Albiac-Murillo, J. D. Connor, R. Hassan, and L. Meza González (editors), Drought in Arid and Semi-Arid Regions. Springer, New York.

Bachand, P. A. M., S. B. Roy, N. Stern, J. Choperena, D. Cameron, and W. R. Horwath. 2016. On-farm flood capture could reduce groundwater overdraft in Kings River Basin. California Agriculture 70:200-207. https://doi.org/10.3733/ca.2016a0018.

Barnes, G. W., Jr., and F. I. Chung. 1986. Operational planning for California water system. Journal of Water Resources Planning and Management 112:71-86.

Bauer, S., J. Olson, A. Cockrill, M. van Hattem, L. Miller, M. Tauzer, and G. Leppig. 2015. Impacts of surface water diversions for marijuana cultivation on aquatc habitat in four northwestern California watersheds. PLoS One 10(3): e0120016. http://dx.doi.org/10.1371/journal.pone.0120016.

Berg, N., and A. Hall. 2015. Increased interannual precipitation extremes over California under climate change. Journal of Climate 28:6324-6334. http://dx.doi.org/10.1175/JCLI-D-14-00624.1.

Berghuijs, W. R., R. A. Woods, and M. Hrachowitz. 2014. A precipitation shift from snow towards rain leads to a decrease in streamflow. Nature Climate Change 4: 583-586. http://www.nature.com/nclimate/journal/v4/n7/full/nclimate2246.html.

Bunn, S. E., and A. H. Arthington. 2002. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. Environmental Management 30:492-507.

Cahill, R., and J. Lund. 2013. Residential water conservation in Australia and California. Journal of Water Resources Planning and Management 139:117-121. http://ascelibrary.org/doi/abs/10.1061/(ASCE)WR.1943-5452.0000225.

California Department of Finance, Population Projections for California and its Counties, 2016 Baseline Series. . http://www.dof.ca.gov/Forecasting/Demographics/Projections/

California Department of Water Resources (DWR), and U.S. Bureau of Reclamation. 2016. Bay Delta Conservation Plan/California WaterFix Final EIS/EIR. Appendix 3A.

California Natural Resources Agency, California Department of Food and Agriculture, California Environmental Protection Agency. 2014. California Water Action Plan. http://resources.ca.gov/california_water_action_plan/

California Natural Resources Agency, California Department of Food and Agriculture, California Environmental Protection Agency. 2016. 2016 Water Action Plan Update. http://resources.ca.gov/california_water_action_plan/

California Natural Resources Agency. 2016. Delta Smelt Resiliency Strategy. http://resources.ca.gov/docs/Delta-Smelt-Resiliency-Strategy-FINAL070816.pdf.

Castillo, G., J. Morinaka, J. Lindberg, R. Fujimura, B. Baskerville-Bridges, J. Hobbs. 2012. Pre-Screen Loss and Fish Facility Efficiency for Delta Smelt at the South Delta's State Water Project, California. San Francisco Estuary and Watershed Science, 10(4). http://escholarship.org/uc/item/28m595k4#page-7

Castle, S. L., B. F. Thomas, J. T. Reager, M. Rodell, S. C. Swenson, and J. S. Famiglietti. 2014. Groundwater depletion during drought threatens future water security of the Colorado River Basin. Geophysical Research Letters 41: 5904–5911. http://onlinelibrary.wiley.com/doi/10.1002/2014GL061055/epdf.

Cayan, D. R., P. D. Bromirski, K. Hayhoe, M. Tyree, M. D. Dettinger, and R. E. Flick. 2008. Climate change projections of sea level extremes along the California coast. Climate Change 87 (Suppl. 1): S57-S73. http://link.springer.com/article/10.1007/s10584-007-9376-7.

Chang, H., and M. R. Bonnette. 2016. Climate change and water-related ecosystem services: impacts of drought in California, USA. Ecosystem Health and Sustainability 2(12): e01254. http://onlinelibrary.wiley.com/doi/10.1002/ehs2.1254/epdf.

Cloern, J. E., and A. D. Jassby. 2012. Drivers of change in estuarine-coastal ecosystems: Discoveries from four decades of study in San Francisco Bay, Rev. Geophys., 50, RG4001, doi:10.1029/2012RG000397.

Cook, B. I., T. R. Ault, and J. E. Smerdon. 2015. Unprecedented 21st century drought risk in the American Southwest and Central Plains. Science Advances 1: e1400082. http://advances.sciencemag.org/content/1/1/e1400082.

Das, T., E. P. Maurer, D. W. Pierce, M. D. Dettinger, and D. R. Cayan. 2013. Increases in flood magnitudes in California under warming climates. Journal of Hydrology 501: 101-110. http://dx.doi.org/10.1016/j.jhydrol.2013.07.042.

Delta Stewardship Council. 2016. 19 Principles for Water Conveyance in the Delta, Storage Systems, and for the Operation of Both to Achieve the Coequal Goals – FINAL. http://deltacouncil.ca.gov/docs/19-principles-water-conveyance-delta-storage-systems-and-operation-both-achieve-coequal-goals

Dettinger, M. 2016a. Historical and future relations between large storms and droughts in California. San Francisco Estuary and Watershed Science 14(2): article 1. http://dx.doi.org/10.15447/sfews.2016v14iss2art1.

Dettinger, M., J. Anderson, M. Anderson, L. Brown, D. Cayan, and E. Maurer. 2016b. Climate change and the Delta. San Francisco Estuary and Watershed Science 14(3): Article 5. http://dx.doi.org/10.15447/sfews.2016v14iss3art5.

Dettinger, M. D., and B. L. Ingram. 2013. The coming megafloods. Scientific American 308: 64-71. http://www.nature.com/scientificamerican/journal/v308/n1/pdf/scientificamerican0113-64.pdf.

Dettinger, M. D., F. M. Ralph, T Das, P. J. Neiman and D. R. Cayan. 2011. Atmospheric rivers, floods and the water resources of California. Water 3:445-478. http://www.mdpi.com/2073-4441/3/2/445.

Dettinger, M., B. Udall, and A. Georgakakos. 2015. Western water and climate change. Ecological Applications 25: 2069-2093. http://onlinelibrary.wiley.com/doi/10.1890/15-0938.1/full.

Differbaugh, N. S., D. L. Swain, and D. Touma. 2015. Anthropogenic warming has increased drought risk in California. PNAS 112:3931-3936. http://www.pnas.org/content/112/13/3931.abstract.

DiFrancesco, K. N., and D. D. Tullos. 2014. Flexibility in water resources management: review of concepts and development of assessment measures for flood management systems. Journal of the American Water Resources Association 50:1527-1539. http://onlinelibrary.wiley.com/doi/10.1111/jawr.12214/epdf.

DiFrancesco, K. and D. Tullos. 2015. Assessment of flood management systems' flexibility with application to the Sacramento River Basin, California, USA. International Journal of River Basin Management 13:271-284. www.tandfonline.com/doi/abs/10.1080/15715124.2014.917316.

Elias, E., A. Rango, R. Smith, C. Maxwell, C. Steele, and K. Havstad. 2016. Climate change, agriculture and water resources in the southwestern United States. Journal of Contemporary Water Research & Education 158:46-61. http://onlinelibrary.wiley.com/doi/10.1111/j.1936-704X.2016.03218.x/epdf.

Famiglietti, J. S., M. Lo, S. L. Ho, J. Bethune, K. J. Anderson, T. H. Syed, S. C. Swenson, C. R. deLinage, and M. Rodell. 2011. Satellites measure recent rates of groundwater depletion in California's Central Valley. Geophysical Research Letters 38: L03403.doi:10.1029/2010GL046442.

Farr, G. T., C. Jones, and Z. Liu. 2015 Progress Report: Subsidence in the Central Valley California. California Department of Water Resources: Sacramento, California. 34 pp. http://www.water.ca.gov/groundwater/docs/NASA_REPORT.pdf.

Ficklin, D. L., I. T. Stewart, and E. P. Maurer. 2013. Effects of climate change on stream temperature, dissolved oxygen, and sediment concentration in the Sierra Nevada in California. Water Resources Research 49: 2765-2782.

Feinstein, L., R. Phurisamban, A. Ford, C. Tyler, and A. Crawford. 2017. Drought and Equity in California. The Pacific Institute. January 2017.

Fleenor, W. E., W. A. Bennett, P. B. Moyle, and J. R. Lund. 2010. On developing prescriptions for freshwater flows to sustain desirable fishes in the Sacramento-San Joaquin Delta. Center for Watershed Sciences. https://watershed.ucdavis.edu/files/biblio/Fish_Flows_for_the_Delta_15feb2010.pdf

Fleenor, W. E., and F. Bombardelli. 2013. Simplified 1-D hydrodynamic and salinity transport modeling of the Sacramento–San Joaquin Delta: sea level rise and water diversion effects. San Francisco Estuary and Watershed Science 11(4): article 2. http://escholarship.org/uc/item/3km0d0kt.

Fleenor, W., E. Hanak, J. Lund, and J. Mount. 2008. Delta Hydrodynamics and Water Quality with Future Conditions, Technical Appendix C. Comparing Futures for the Sacramento San Joaquin Delta. San Francisco: Public Policy Institute of California.

Fournier, E. D., A. A. Keller, R. Geyer, and J. Frew. 2016. Investigating the energy-water usage efficiency of the reuse of treated municipal wastewater for artificial groundwater recharge. Environmental Science and Technology 50:2044-2053. http://pubs.acs.org/doi/abs/10.1021/acs.est.5b04465.

Georgakakos, A. P., H. Yao, M. Kistenmacher, K. P. Georgakakos, N. E. Graham, F.-Y. Cheng, C. Spencer, and E. Shamir. 2012. Value of adaptive water resources management in Northern California under climatic variability and change: reservoir management. Journal

of Hydrology 412: 34-46. http://www.sciencedirect.com/science/article/pii/S0022169411003015.

Gingras, M. 1997. Mark-recapture experiments at Clifton Court Forebay to estimate pre-screening loss to juvenile fishes: 1976-1993. Interagency Ecological Program. Technical Reoprt 55. California Department of Water Resources. Sacramento, California. http://www.water.ca.gov/iep/docs/tech_rpts/TR55.Mark-Recapture%20Experiments%20at%20Clifton%20Court%20Forebay%20to%20Estimate%20Pre-Screening%20Loss%20to%20Juvenile%20Fishes%201976-1993%20-%20Final%20Version.pdf

Goulden, M. L. and R. C. Bales. 2014. Mountain runoff vulnerability to increased evapotranspiration with vegetation expansion. Proceedings of the National Academy of Sciences of the United States of America. http://www.pnas.org/content/111/39/14071.full.pdf

Gray, B., E. Hanak, R. Frank, R, Howitt, J. Lund, L. Szepthycki, B. Thompson. 2015. Allocating California's Water: Direction for Reform. Public Policy Institute of California.

Griggs, G., J. Árvai, D. Cayan, R. DeConto, J. Fox, H.A. Fricker, R.E. Kopp, C. Tebaldi, E.A. Whiteman. 2017. Rising Seas in California: An Update on Sea-Level Rise Science. California Ocean Protection Council Science Advisory Team Working Group. California Ocean Science Trust. April 2017.

Grimaldo, L.F., T. Sommer, N. Van Ark, G. Jones, E. Holland, P. Moyle, B. Herbold, P. Smith. 2009. Factors Affecting Fish Entrainment into Massive Water Diversions in a Tidal Freshwater Estuary: Can Fish Losses be Managed? North American Journal of Fisheries Management 29:1253–1270, American Fisheries Society.

Grossman, Gary D. 2016. Predation on Fishes in the Sacramento–San Joaquin Delta: Current Knowledge and Future Directions. San Francisco Estuary and Watershed Science, 14(2). jmie_sfews_31669. Retrieved from: http://escholarship.org/uc/item/9rw9b5tj

Hanak, E., J. Lund. A. Dinar, B. Gray, R. Howitt, J. Mount, P. Moyle, B. Thompson. 2011. Managing California's Water: From Conflict to Reconciliation. Public Policy Institute of California. http://ppic.org/content/pubs/report/R_211EHR.pdf

Hanak, E., J. Lund, B. Thompson, W.B. Cutter, B. Gray, D. Houston, R. Howitt, K. Jessoe, G. Libecap, J. Medellín-Azuara, S. Olmstead, D. Sumner, D. Sunding, B. Thomas, R. Wilkinson. 2012. Water and the California Economy. Technical Appendix. Public Policy Institute of California. http://www.ppic.org/content/pubs/other/512ehR_appendix

Hanak, E., J. Lund. J. Durand, W. Fleenor, B. J. Medellín-Azuara, J. Mount, P. Moyle, C. Phillips, B. Thompson. 2013. Stress Relief: Prescriptions for a Healthier Delta Ecosystem. Public Policy Institute of California.

Hanak, E., J. Mount, C. P. Chappelle, J. Lund, J. Medellín-Azuara, P. Moyle, and N. Seavy. 2015. What If California's Drought Continues? Public Policy Institute of California. http://www.ppic.org/content/pubs/report/R_815EHR.pdf.

Hanak, E., J. Lund, B. Arnold, A. Escriva-Bou, B. Gray, S. Green, T. Harter, R. Howitt, D. MacEwan, J. Medellín-Azuara, P. Moyle, and N. Seavy. 2017. Water Stress and a Changing San Joaquin Valley. Public Policy Institute of California.

Healey, M., P. Goodwin, M. Dettinger, R. Norgaard. 2016. The State of Bay–Delta Science 2016: An Introduction. San Francisco Estuary and Watershed Science, 14(2). jmie_sfews_31666. Retrieved from: http://escholarship.org/uc/item/9k43h252

Ho, M., U. Lall, M. Allaire, N. Devineni, H. H. Kwon, I. Pal, D. Raff, and D. Wegner. 2017. The future role of dams in the United States of America, Water Resources Res., 53, 982–998, doi:10.1002/2016WR019905.

Howitt, R.E., D. MacEwan, J.D. Medellín-Azuara, J. R. Lund, 2010. Economic Modeling of Agriculture and Water in California Using the Statewide Agricultural Production Model. University of California, Davis. http://deltarevision.com/2009_even_more_docs/v4c04a02_cwp2009.pdf

Howitt, R. E., D. MacEwan, J. Medellín-Azuara, J. Lund, and D. Sumner. 2015. Economic Analysis of the 2015 Drought for California Agriculture. University of California, Davis: Davis, California. 16 pp.

Huang, G., T. Kadir, and F. Chung. 2012. Hydrological response to climate warming: The Upper Feather River watershed. Journal of Hydrology 426-427:138-150. http://dx.doi.org/10.1016/j.jhydrol.2012.01.034.

Jenkins, M. W., J. R. Lund, R. E. Howitt, A. J. Draper, S. M. Msangi, S. K. Tanaka, R. S. Ritzema, and G. F. Marques. 2004. Optimization of California's water supply system: results and insights. Journal of Water Resources Planning and Management 130: 271-280.

Jepsen, S. M., T. C. Harmon, M. W. Meadows, and C. T. Hunsaker. 2016. Hydrologic influence on changes in snowmelt runoff with climate warming: Numerical experiments on a mid-elevation catchment in the Sierra Nevada, USA. Journal of Hydrology 533: 332-342. http://dx.doi.org/10.1016/j.jhydrol.2015.12.010.

Kiparsky, M., B. Joyce, D. Purkey, C. Young. 2014. Potential impacts of climate warming on water supply reliability in the Tuolumne and Merced River Basins, California. PLoS ONE 9(1): e84946. http://dx.doi.org/10.1371/journal.pone.0084946.

Kistenmacher, M., and A. P. Georgakakos. 2015. Assessment of reservoir system variable forecasts. Water Resources Research 51: 3437–3458. http://onlinelibrary.wiley.com/doi/10.1002/2014WR016564/epdf.

Lund, J. 2015. Integrating social and physical sciences in water management. Water Resources Research 51:5905-5918. http://onlinelibrary.wiley.com/doi/10.1002/2015WR017125/full.

Lund, J. 2016. California's agricultural and urban water supply reliability and the Sacramento-San Joaquin Delta. San Francisco Estuary & Watershed Science 14 (3): Article 6. http://escholarship.org/uc/item/49x7353k.

Lund, J., E. Hanak, W. Fleenor, R. Howitt, J. Mount, and P. Moyle. 2007. Envisioning Futures for the Sacramento-San Joaquin Delta. Public Policy Institute of California.

Lund, J., E. Hanak, W. Fleenor, W. Bennett, R. Howitt, J. Mount, and P. Moyle. 2008. Comparing Futures for the Sacramento-San Joaquin Delta. Public Policy Institute of California. http://www.ppic.org/content/pubs/report/R_708EHR.pdf.

Lund, J., A. Munévar, A. Taghavi, M. Hall, and A. Saracino. 2014. Integrating Storage in California's Changing Water System. UC Davis. https://watershed.ucdavis.edu/library/integrating-storage-californias-changing-water-system.

Luoma, S. N., C. N. Dahm, M. Healey, and J. N. Moore. 2015. Challenges facing the Sacramento-San Joaquin Delta: complex, chaotic or simply cantankerous? San Francisco Estuary and Watershed Science 1(3): article 7. http://dx.doi.org/10.15447/sfews.2015v13iss3art7

Mann, M. E., S. Rahmstorf, K. Kornhuber, B.A. Steinman, S.K. Miller, and D. Coumou. 2017. Influence of Anthropogenic Climate Change on Planetary Wave Resonance and Extreme Weather Events. Sci. Rep. 7, 45242; doi: 10.1038/srep45242. http://www.nature.com/articles/srep45242

Medellín-Azuara, J.D., R. Howitt, E. Hanak, J. Lund, W.E. Fleenor. 2014. Agricultural Losses from Salinity in California's Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science. http://escholarship.org/uc/item/4b7295m9

Medellín-Azuara, J., D. MacEwan, R. E. Howitt, G. Koruakos, E. C. Dogrul, C. F. Brush, T. N. Kadir, T. Harter, F. Melton, and J. R. Lund. 2015. Hydro-economic analysis of

groundwater pumping for irrigated agriculture in California's Central Valley, USA. Hydrogeology Journal 23: 1205-1216. https://link.springer.com/article/10.1007/s10040-015-1283-9.

Mount, J., W. Bennett, J. Durand, W. Fleenor, E. Hanak, J. Lund, and P. Moyle. 2012. Aquatic Ecosystem Stressors in the Sacramento-San Joaquin Delta. Public Policy Institute of California. http://www.ppic.org/main/publication.asp?i=1024

Mount, J., and R. Twiss. 2005. Subsidence, sea level rise, and seismicity in the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science 3(1): article 5. http://escholarship.org/uc/item/4k44725p.

Moyle, P. B. 2014. Novel aquatic ecosystems: the new reality for streams in California and other Mediterranean climate regions. River Research and Applications 30: 1335–1344. http://onlinelibrary.wiley.com/doi/10.1002/rra.2709/epdf.

Moyle, P. B. and W. A. Bennett. 2008. Comparing Futures for the Sacramento-San Joaquin Delta, Technical Appendix D: The Future of the Delta Ecosystem and Its Fish. Public Policy Institute of California. www.waterboards.ca.gov/waterrights/water_issues/.../moyleandbennett2008.pdf

Moyle, P. B., J. V. E. Katz, and R. Quiñones. 2010. Rapid decline of California's native inland fishes. Center for Watershed Sciences. https://watershed.ucdavis.edu/pdf/Moyle CA fish status-WP.pdf.

Moyle, P. B., J. D. Kiernan, P. K. Crain, and R. M. Quiñones. 2013. Climate change vulnerability of native and alien freshwater fishes of California: A systematic assessment approach. PLoS ONE 8: e63883. http://dx.doi.org/10.1371/journal.pone.0063883.

Moyle, P. B., L. R. Brown, J. R. Durand, J. A. Hobbs. 2016. Delta Smelt: life history and decline of a once-abundant species in the San Francisco Estuary. San Francisco Estuary and Watershed Science 14(2): Article 6. http://dx.doi.org/10.15447/sfews.2016v14iss2art6.

Moyle, P. W. Bennett, J. Durand, W. Fleenor, B. Gray, E. Hanak, J. Lund, and J. Mount. 2012. Where the Wild Things Aren't: Making the Delta a Better Place for Native Species. Public Policy Institute of California. http://www.ppic.org/content/pubs/report/R_612PMR.pdf

National Marine Fisheries Service. 2009. Biological Opinion and Conference Opinion on the Long-Term Central Valley Project and State Water Project Operations Criteria and Plan. Southwest Region. June. Long Beach, California. 844 pp.

National Marine Fisheries Service. 2014. Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of California Central Valley Steelhead. West Coast Region. Sacramento, CA. 427 pp.

National Research Council. 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. National Academies Press, Washington, D.C. https://www.nap.edu/catalog/13389/sea-level-rise-for-the-coasts-of-california-oregon-and-washington.

Nichols, F. H., J. E. Cloern, S. N. Luoma, and D. H. Peterson. 1986. The modification of an estuary. Science 231:567-573.

Null, S. E. 2016. Water supply reliability tradeoffs between removing reservoir storage and improving water conveyance in California. Journal of the American Water Resources Association 52: 350-366. http://onlinelibrary.wiley.com/doi/10.1111/1752-1688.12391/epdf.

Null, S. E., J. Medellín-Azuara, A. Escriva-Bou, M. Lent, and J. R. Lund. 2014. Optimizing the dammed: Water supply losses and fish habitat gains from dam removal in California. Journal of Environmental Management 136: 121-131. http://www.sciencedirect.com/science/article/pii/S0301479714000395.

Null, S. E., and L. Prudencio. 2016. Climate change effects on water allocations with season dependent water rights. Science of the Total Environment 571: 943-954. http://www.sciencedirect.com/science/article/pii/S0048969716315273.

Opperman, J. J., G. E. Galloway, J. Fargione, J. F. Mount, B. D. Richter, and S. Secchi. 2009. Sustainable floodplains through large-scale reconnection to river. Science 326:1487-1488. http://science.sciencemag.org/content/326/5959/1487.

Petts, G. E. 2009. Instream flow science for sustainable river management. Journal of the American Water Resources Association (JAWRA) 45(5):1071-1086.

Pierce, D. W. and D. R. Cayan. 2013. The uneven response of different snow measures to human-induced climate warming. Journal of Climate 26:4148–4167. http://journals.ametsoc.org/doi/pdf/10.1175/JCLI-D-12-00534.1.

Pierce, D. W., T. Das, D. R. Cayan, E. P. Maurer, N. L. Miller, Y. Bao, M. Kanamitsu, K. Yoshimura, M. A. Snyder, L. C. Sloan, G. Franco, and M. Tyree. 2013. Probabilistic estimates of future changes in California temperature and precipitation using statistical and dynamical downscaling. Climate Dynamics 40: 839-856. http://link.springer.com/article/10.1007/s00382-012-1337-9.

Pulido-Velazquez, M., G. F. Marques, J. J. Harou, and J. R. Lund. 2016. Hydroeconomic models as decision support tools for conjunctive management of surface and groundwater. Pages 693-710 in A. J. Jakeman, O. Barreteau, R. J. Hunt, J.-D. Rinaudo, and A. Ross (editors), Integrated Groundwater Management. Springer International Publishing.

Reclamation (U.S. Bureau of Reclamation). 1992. Central Valley Project Improvement Act. 1992. https://www.usbr.gov/mp/cvpia/.

Reclamation. 2008. Water Supply and Yield Study. https://www.usbr.gov/mp/cvp/docs/water-supply-and-field-study.pdf.

Reclamation. 2015. Shasta Temperature Management Plan-Key Components. http://www.usbr.gov/mp/drought/docs/shasta-temp-mgmt-plan-key-components-06-18-15.pdf.

Reclamation. 2016. Sacramento and San Joaquin Rivers Basin Study. https://www.usbr.gov/watersmart/bsp/docs/finalreport/sacramento-sj/Sacramento_SanJoaquin_SUMMARY.pdf

Rheinheimer, D. E., R. C. Bales, C. A. Oroza, J. R. Lund, and J. H. Viers. 2016. Valuing year-to-go hydrologic forecast improvements for a peaking hydropower system in the Sierra Nevada, Water Resources Research 52: 3815-3828. http://onlinelibrary.wiley.com/doi/10.1002/2015WR018295/full.

Robinson, J. D., and F. Vahedifard. 2016. Weakening mechanisms imposed on California's levees under multiyear extreme drought. Climatic Change 137:1-14. http://link.springer.com/article/10.1007/s10584-016-1649-6.

Savtchenko, A. K., G. Huffman, and V. Vollmer. 2015. Assessment of precipitation anomalies in California using TRMM and MERRA data. Journal of Geophysical Research: Atmosphere 120:8206-8215. http://onlinelibrary.wiley.com/doi/10.1002/2015JD023573/full.

Seager, R., M. Ting, C. Li, N. Naik, B. Cook, J. Nakamura, and H. Liu. 2013. Projections of declining surface-water availability for the southwestern United States. Nature Climate Change 3: 482-486. http://www.nature.com/nclimate/journal/v3/n5/full/nclimate1787.html.

Service, R. F. 2007. Delta blues, California style. Science 317:442-445. http://science.sciencemag.org/content/317/5837/442.

Sneed, M., J. Brandt, and M. Solt. 2013. Land subsidence along the Delta-Mendota Canal in the northern part of the San Joaquin Valley, California, 2003-10. U.S. Geological Survey Scientific Investigations Report 2013–5142. http://dx.doi.org/10.3133/sir20135142.

State Water Resources Control Board (SWRCB). 2010. Development of Flow Criteria for the Sacramento–San Joaquin Delta Ecosystem. California Environmental Protection Agency, Sacramento, California.

State Water Resources Control Board ~~(SWRCB)~~. 2013. Communities that Rely on a Contaminated Groundwater Source for Drinking Water.

SWRCB. 2015. Safe Drinking Water Plan for California. June 2015.

Stewart, I. T., D. L. Ficklin, C. A. Carrillo, and R. McIntosh. 2015. 21st century increases in the likelihood of extreme hydrologic conditions for the mountainous basins of the Southwestern United States. Journal of Hydrology 529: 340-353. http://dx.doi.org/10.1016/j.jhydrol.2015.07.043.

U.S. Fish and Wildlife Service. 2008. Biological Opinion on the Coordinated Operations of the Central Valley Project and State Water Project in California. Final. December. Sacramento, California. 410 pp.

Udall, B., and J. Overpeck. 2017. The 21st century Colorado River hot drought and implications for the future. Water Resources Research (Accepted Article). http://onlinelibrary.wiley.com/doi/10.1002/2016WR019638/full.

Vahedifard, F., J. D. Robinson, and A. AghaKouchak. 2016. Can protracted drought undermine the structural integrity of California's earthen levees? Journal of Geotechnical and Geoenvironmental Engineering 142: 02516001. http://ascelibrary.org/doi/full/10.1061/(ASCE)GT.1943-5606.0001465.

Van Lienden, B., A. Munévar, and T. Das. 2014. West-Wide Climate Risk Assessment: Sacramento and San Joaquin Basins Climate Impact Assessment. US Bureau of Reclamation. 66 p. http://www.usbr.gov/watersmart/wcra/docs/ssjbia/ssjbia.pdf.

Walton, D., A. Hall, N. Berg, M. Schwartz, F. Sun. 2017. Incorporating snow albedo feedback into downscaled temperature and snow cover projections for the Sierra Nevada. UCLA Center for Climate Science. https://www.ioes.ucla.edu/wp-content/uploads/Summary_Walton_Temperature.pdf

Weiler, N. 2014. Satellites show true extent of California drought, *Eos*, *95*, doi:10.1029/2014EO020819.

Whipple, A., Grossinger, R. M., Rankin, D., Stanford, B., and Askevold, R. A. 2012. Sacramento-San Joaquin Delta Historical Ecology Investigation: Exploring Pattern and Process. San Francisco Estuary Institute, Richmond, California.

Williams, A. P., R. Seager, J. T. Abatzoglou, B. I. Cook, J. E. Smerdon, and E. R. Cook. 2015. Contribution of anthropogenic warming to California drought during 2012–2014. Geophysical Research Letters 42:6819-6828. http://onlinelibrary.wiley.com/doi/10.1002/2015GL064924/full.

Wilson, T. S., B. M. Sleeter, and D. R. Cameron. 2016. Future land-use related water demand in California. Environmental Research Letters 11:054018. http://iopscience.iop.org/article/10.1088/1748-9326/11/5/054018.

Working Group on California Earthquake Probabilities. 2003. Earthquake Probabilities in the San Francisco Bay Region: 2002–2031. U.S. Geological Survey Open-File Report 03-214. https://pubs.usgs.gov/of/2003/of03-214/OFR-03-214_FullText.pdf.

Yarnell, S. M., G. E. Petts, J. C. Schmidt, A. A. Whipple, E. E. Beller, C. N. Dahm, P. Goodwin, and J. Viers. 2015. Functional flows in modified riverscapes: Hydrographs, habitats, and opportunities. BioScience 65:953-972. https://doi.org/10.1093/biosci/biv102.